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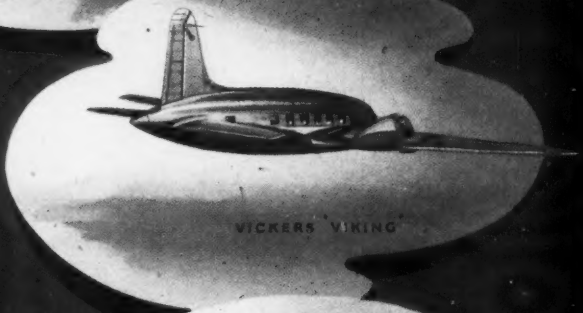

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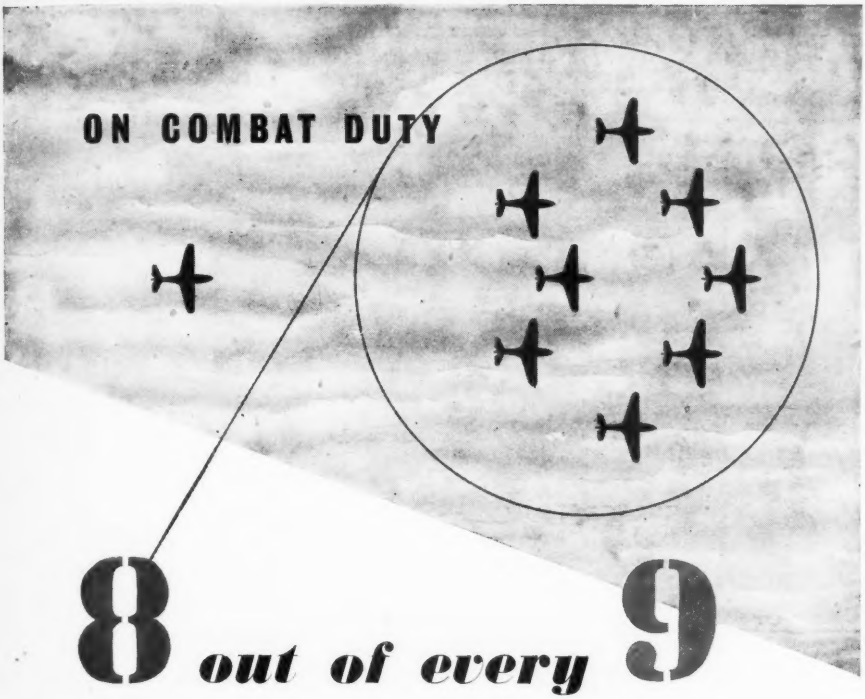

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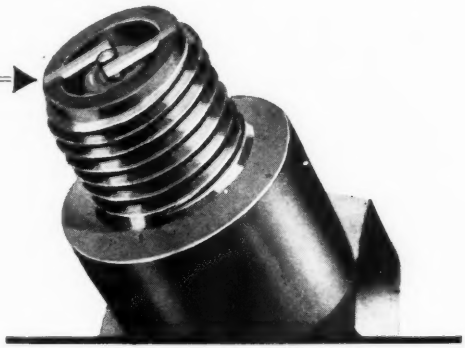

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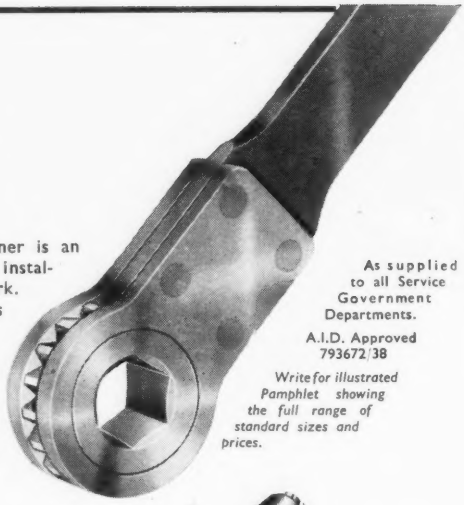

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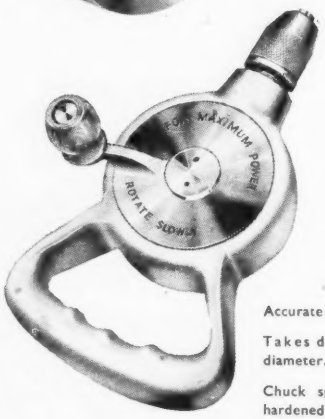

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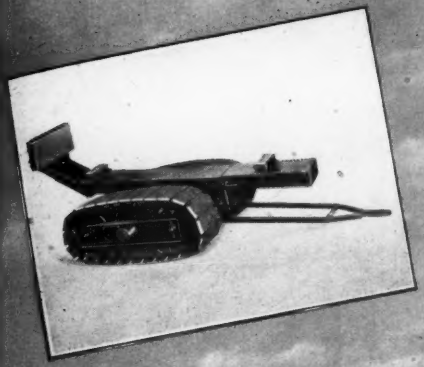

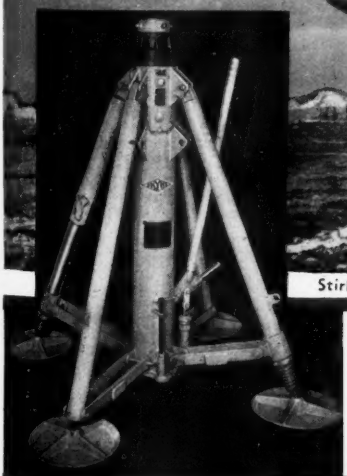

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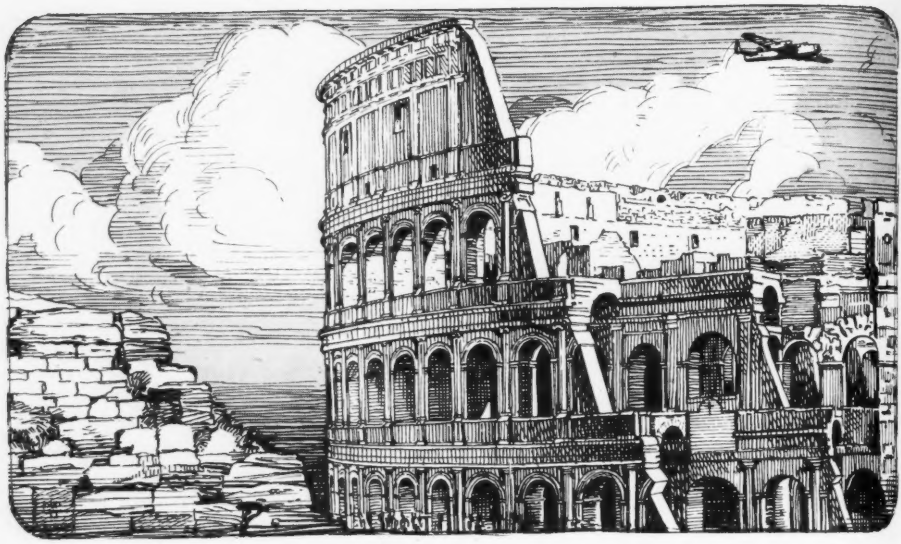

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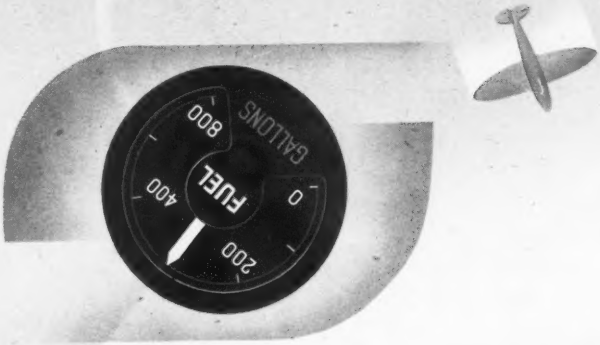

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FREDERICK WILLIAM LANCHESTER

1868-1946

BY THE DEATH of Frederick William Lanchester aviation has lost one who will take a high place on the roll of aeronautical fame.

Born only a few months after the Society had held the first aeronautical exhibition ever held in this country. Lanchester was educated privately and at the Royal College of Science.

In 1889 Lanchester became Assistant Works Manager at Messrs. T. B. Barker's of Saltley, Birmingham, and turned his energies towards the development of the gas engine, producing his well-known gas engine starter, and developing engines of higher speeds than had been in use. It was at this time that he began to work in close association with Sir Dugald Clark.

In 1894 he began the construction of the first Lanchester motor car and in 1899 the Lanchester Motor Company was formed, with Lanchester as Chief Engineer and General Manager.

These years of development showed his remarkable ability and foresight. The Motor Car Industry, indeed, owes as great a debt to Lanchester as does aeronautics. To him were due the epicyclic change-speed gear, pre-selector gear, wire wheels, electric ignition, direct-driven top gear and normal transmission on the rear axle.

From 1904 to 1914 he became Consulting Engineer to the Lanchester Company, from 1909 to 1929 he was Consulting Engineer and Technical Adviser to the Daimler Company and from 1928 to 1930 Consulting Engineer to William Beardmore's on Diesel engines.

In 1910 he brought out his crankshaft damper and in 1911 his harmonic balancer, which were important contributions to the problem of torsional oscillation of internal combustion engines. His pendulum accelerometer for measuring and recording tractive and braking effort appeared about this time and his gyroscopic true plumb and turn indicator was widely used in the Air Force in the 1914-18 War.

An indication of his wide interest was the production in 1927 of an acoustic tube moving-coil loud speaker and diffractaphone aperture which ensured the most perfect distribution of tones of different pitch in a concert hall or in the open air. He was the

author of papers which varied from Aerodynamics to the Theory of Dimensions, from Gearing to Relativity, from The Energy Balance Sheet of the Internal Combustion Engine to Discontinuities in the Normal Field of Vision.

It is in the field of aeronautics, however, that the fame of Lanchester will surely rest.

At the age of 26, in 1894, he read to the Birmingham Natural History and Philosophical Society a paper in which he first put forward the now well-known conception of the vortex or circulation theory of sustentation in flight. It was a paper of the highest importance. During the next three years Lanchester revised it and submitted it in 1897 to the Physical Society, which rejected it, and he had to wait until the publication of his own books on Aerodynamics and Aerodonetics in 1907.

These two books form the foundations of flight as we know it to-day. They revealed an insight into aerodynamic problems which was all the more astounding when so little was known.

On the occasion of the award of the 1945 James Watt International Medal by the Institute of Mechanical Engineers to Lanchester, Sir Melvill Jones, Chairman of the Aeronautical Research Council, said:—

"The ideas and theories contained in the volumes have since been extended and developed by subsequent authors and some have been restated in mathematical terms of a more conventional kind than those used by the author. For this reason many who now make constant use of Lanchester's ideas may not appreciate fully from whom they originated, but no one conversant with the science as it now stands can fail to be impressed, on reading the volumes, with the author's astounding vision and grasp of the subject, at a time when very little was known about it and the experimental data, beyond what he himself had obtained with the simplest apparatus, were almost non-existent."

It was in his Aerodynamics that Lanchester published the first statement about induced drag and showed the generation of the circulatory motion in the air, which takes the form of a pair of vortices from the wing tips. In 1915 in a further paper, he showed that induced drag depended primarily on wing span.

Lanchester also drew attention in his book to the importance of skin friction, which Langley had asserted was of little importance. His ideas at the time were revolutionary and it took many years before they were translated into the streamline aircraft of the present day.

In this astonishing volume on Aerodynamics, Lanchester also discussed scale effect and explained the use of Reynolds Number, sometimes wrongly claimed for Lord Rayleigh, who himself did not claim priority.

The first volume to be published in 1907, under the title Aerodonetics, laid down the main features of stability and control, entirely as the result of his own observations on small gliding models, a very remarkable achievement.

As early as 1897 Lanchester filed a patent (No. 3608) disclosing some of the results of his research. Here he mentioned, which was not obvious at the time, that in an aeroplane the tail plane adjustment controls the speed. He also made reference to wing warping, though it was not in such precise terms as to upset the claim of the Wright brothers.

Space does not permit a review of the many papers Lanchester published. Sufficient has been said, however, to indicate the outstanding quality of his work and with the years his reputation will continue to grow. His was a master mind.

Lanchester's work has already received international recognition. He was a Fellow of the Royal Society, and an Honorary Doctor of Laws, an Honorary Fellow of the Institute of Mechanical Engineers, and of the Royal Aeronautical Society. He was awarded the Gold Medal of the Society in 1926, when he read the Wilbur Wright Memorial Lecture, the Daniel Guggenheim Gold Medal in 1931 and the Ewing Medal of the Institution of Civil Engineers in 1941.

From 1909 to 1920 he was a member of the Advisory Committee on Aeronautics and contributed many papers to its Reports and Memoranda.

Lanchester will take his place with such figures as Sir George Cayley and Stringfellow in the history of British aeronautics. He was a man of great personality, a brilliant scientist and an outstanding engineer. He had an independence of outlook and a freedom of spirit which brought great opposition from the vested minds which he fought so long and so ably.

Few people knew that Lanchester was also a poet who published privately two slim volumes of verse under the name of Paul Netherton Herries. In one he wrote:—

> " He is no more !
> Whose countless friends, belov'd of him, stand silent now;
> Born to high achievement, yet frugally he lived,
> Bearing the yoke of service here with dignity.
> His soul was in his work, which, living on, bears fruit:
> So doth a soul attain to immortality."

It is a fitting epitaph to a great pioneer.

The 685th Lecture read before the Society

THE SELECTION OF ENGINEERING PERSONNEL

by

FRANK HOLLIDAY, B.Sc., Associate Fellow

Mr. Frank Holliday was for some years Apprentice Supervisor and Head of the Technical School at Vickers-Armstrongs, Ltd., Weybridge. He has been investigating problems in connection with the selection of Engineering Personnel since 1938. *He is an Associate Fellow of the Society.*

A MEETING of the Royal Aeronautical Society was held in the lecture hall of the Institution of Civil Engineers, Great George Street, London, S.W.1, on Wednesday, February 13th, 1946, at which a paper by Mr. Frank Holliday on "The Selection of Engineering Personnel" was presented and discussed. In the Chair, the President, Sir Frederick Handley Page.

THE PRESIDENT, introducing Mr. Holliday, said that he had been investigating problems in connection with the selection of engineering personnel since 1938.

Broadly speaking, people who were engaged in the Aeronautical Industry had to deal with two problems. One was the buying of ordinary machinery and installing it in the works, and the other was what the Americans called the "hiring of personnel." The buying and installation of machinery was comparatively easy, because it could be put down in a given place where it would remain and would not grow awkward corners and spikes, and so on. The problem of selecting personnel was much more difficult, for it involved fitting in individuals with other individuals or pieces of human machinery, and unfortunately, sometimes they tended to grow spikes or quills in all directions in the manner of the porcupine. The problem of selecting those who would fit in and work easily was one with which Mr. Holliday was well qualified to deal.

INTRODUCTION.

THIS paper had not been easy to prepare because any adequate treatment of recent investigations and research would have to pre-suppose in the engineer-reader a whole body of information which it would not be reasonable to suppose he has. Further, the author's pitch had been cleared, for nearly three years ago the Institution of Production Engineers published a paper by him entitled: "A Survey of Selection and Allocation for Engineering Occupations."

After much thought, he decided to deal mostly with some of the fundamental ideas underlying selection, and to offer a bibliography to assist readers who so desire, to gain further knowledge of the underlying facts and theories of Occupational Psychology and of the application of these to investigations which have been carried out in the allied fields of vocational guidance and selection, and to procedures which are being increasingly used.

SOME PSYCHOLOGICAL CONSIDERATIONS.

For over two thousand years psychology continued as it had begun, a branch of metaphysics, the chief method of which was introspection, and the chief subject the mind generally. During the early part of the nine-

teenth century it took a different turn. Differences between one mind and another which had previously been ignored or averaged away, began to be studied as such. The psychologist, influenced by the growth of other sciences, notably physics, himself took to the laboratory.

Following on Lavater's treatize on physiognomy (1772), according to which a man's disposition and abilities were to be inferred from the features and expression of his face; on Gall's system of phrenology, propounded thirty years later, according to which a large number of complex propensities were located in various areas or "organs" of the brain, and the development of which was to be inferred from the relative prominence of the overlying regions of the skull; and on the work of the Italian criminologist Lombroso, who claimed to be able to recognize defective intelligence and degenerate character from certain visible marks or malformations—his stigmata of degeneracy; many investigations were made to determine whether there was any connection between physical characteristics, such as various dimensions of the skull, and mental qualities such as intelligence. Many investigations were also concerned with the relation between intelligence and the lower sense of touch and the higher senses of hearing and vision. The general conclusion to be drawn from these investigations was that the only safe guides to the diagnosis of mental characteristics were mental rather than physical criteria.

Mere scrutiny of two orders of size or of merit of a group of students between, say, width of skull and intelligence as estimated by their teacher, was at first the only method available for investigating whether or not there was any connection between these. The method of correlation announced by the great English scientist, Sir Francis Galton, was a mathematical device for the measurement of the extent to which two such orders of merit were related. If there was complete agreement, the coefficient of correlation was $+1$, and if there was perfect disagreement -1. No agreement at all gave a correlation of zero.

Clearly, this was a great advance, enabling the relationship which had hitherto not been apparent between two characteristics, to be demonstrated. Galton also suggested the method of percentiles which will be mentioned later in this paper.

To Dr. Alfred Binet, who had the task of sorting out Paris school children who were so dull that they were incapable of profiting by the ordinary instruction offered, and who, it should be added, solved this problem with signal success, we owe the concept of an age-scale of intelligence. By comparing a child's performance on various tests with the performance of other children of various ages he was able to see whether the child's "mental age" was in advance or in retard of his chronological age. Binet considered that in order to measure intelligence it was necessary to sink not one shaft but several. Accordingly his plan was to ask a relatively large number of short questions covering a wide field—a point of great importance in the art of examining.

Group tests were developed, which, of course, widened the possibility of research. New light was thrown on the age-old question of the extent to which man's make-up was the result of nature on the one hand and of nurture on the other—of inborn characteristics handed down to him by his ancestors, as against those which education and circumstance can bestow. If a boy was intellectually dull when he was young, would he become brighter as a result of education and training?

This was answered in the negative by the discovery that children's intelligence quotient, *i.e.*, the ratio of their mental age as determined by intelligence tests to their chronological age, remained constant—at least up to the time they were about 16 years of age. While education and training obviously increased a boy's power to use what intelligence he had, they apparently did nothing to increase the quota with which he was born. Subsequent

mental age could be predicted from a reliable estimate of it made at quite an early age.

Burt tried out tests of reasoning in this country in the first decade of this century, coming to the conclusion that the higher and more complex the activity tested, the closer was its correlation with intelligence.

The concept of correlation was used to great effect by Spearman, whose "two-factor" theory, of such importance in psychology, holds that all mental activities depend upon at least two factors, one of which is a general factor called "g" common to them all, and the other a specific factor peculiar to each activity. It is now commonly agreed that there is a general factor of intelligence involved in all purposeful activity; a considerable number of group factors, each of which is common to a particular group of activities; and a number of specific factors each of which is peculiar to a single, simple form of activity.

"There is undoubtedly a group factor underlying 'mechanical' and certain other abilities, which concern the readiness to perceive the sizes, shapes, and spatial relations of objects. With this 'spatial' factor certain tests that have been devised prove by mathematical analysis to be highly saturated. In the daily work of the engineer this factor is involved in his translation of two-dimensional diagrams into three-dimensional objects, and *vice versa* (as in the reading and making of drawings), in the pattern-maker's and moulder's ability to imagine the 'inverse' of a pattern or object, etc. There is reason to believe that it is also involved in the engineer's 'machine sense,' as shown in his ability to realize how a machine works—how its parts fit together, how, if one of the parts is set in motion, another will move, etc."*

Aptitude tests for the measurements of mechanical aptitude have been developed for some years and are now very successful. Although it is commonly said that intelligence tests have a higher validity than aptitude tests, experience in engineering suggests that this is not so. Intelligence tests came first into the field, but much fruitful experience has geen gained with aptitude tests in the past few years.

NORMS AND PERCENTILES.

The idea of a "norm," which was implicit in Binet's work, is one of such importance in the field of selection that it is worth dilating upon a little. A candidate's performance on a test should not be judged with reference to some ideal standard that the selector has in mind, but with reference to a sound, objective scale of performance. Further, until an objective frame of reference is built up, a candidate's performance cannot be assessed at all accurately. An example may make this clear.

Suppose an attempt is being made to assess a man's fitness for a job in which his hearing is of vital importance—a job, in which he has continually to receive messages through earphones. How is the acuity or otherwise of the man's hearing to be assessed? Not just by an interview, as this would only enable the man who was hard of hearing to be distinguished and then it would not be possible to say just *how* hard of hearing he was.

Suppose a test is evolved which consists of a gramophone record of a voice reading out a series of figures, four at a time, with appropriate pauses between each set of figures, the voice becoming gradually softer and softer until it is quite inaudible. The sets of figures are to be written as they are heard, and the measure of the man's hearing is the extent to which he can continue to write down the correct sets of figures.

By giving the test under identical conditions to a substantial number of men, and writing down all their scores in order of decreasing size, it is easy to find the percentage number of men who equal or exceed a whole range of scores. If the test gives a satisfactory distribution of scores a graph can be drawn

* C. S. Myers. "Psychology as applied to Engineering" (James Forrest Lecture for 1942), *Journal of the Institution of Civil Engineers*, Vol. XVII, pp. 295-315, February, 1942.

that will resemble Figure 1, when irregularities are evened out. If the batch of men from whose test scores the graph is drawn is representative, then any particular score may be related to the percentage of men who make a score as good or better. A man's score corresponds to the 90th percentile if it is better than the score obtained by 90 per cent. of the representative group tested. By designating scores corresponding to the top and bottom 10 per cent. as excellent and poor respectively, and those corresponding to the next top and bottom 20 per cent. as good and fair respectively, the rest being average, a five-point rating is made. It is now possible to say *how* good is the man's hearing.

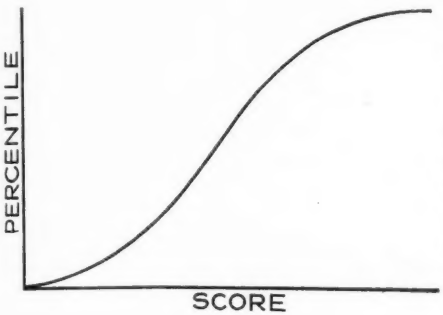

Fig. 1

Those who are aware of the difficulties of selection will endeavour to add precision to their interpretation of test and other scores, by referring them to such a *scale* or *norm* of *actual performance*. To begin with, this scale may be the published norms applying to the performance of, say, secondary school boys of sixteen years of age on a particular test. But each selector should build up his own norms as his experience with a particular test grows.

THE PROBLEM.

The principal factors of success are ability, knowledge, character, skill and physique. In order to select effectively, we need to know which of these factors are relatively most important in each occupation, and then to devise some reliable means of measuring each apart from the influence of the others.

This necessitates a knowledge of the individual on the one hand and a knowledge of the job on the other. Further, it involves interpreting that knowledge of the individual in terms of the job requirements. Clearly, both the individuals and the occupations must be studied according to the same plan, and described in the same terms.

For the job of technical representative, qualities of personality and character will perhaps be of over-riding importance; for that of apprentice toolmaker the aptitude which with suitable experience will show itself in manual skill. In selecting youths who will later, it is hoped, become design draughtsmen, a fairly high minimum of intelligence and of knowledge, particularly of mathematics and physical science, is necessary to ensure that they may proceed successfully with a suitable course of study and further, good endowment with those aptitudes, which later will show themselves in a ready ability to visualize mechanisms and structures and, generally, to think "in the solid."

Just where the emphasis will be placed, whether on ability or knowledge, on character or skill, or physique, will clearly depend on the job, but in all cases the successful selector will be clear in his mind as to the qualities he is looking for and their relative importance.

OCCUPATIONAL ANALYSIS

Adequate job analysis lies at the heart of all vocational guidance and selection. It is also a pre-requisite to effective vocational training.

A complete job analysis will give methods and conditions of entry, pay, hours and conditions of work, prospects, etc., and descriptions of the materials, tools and processes used. Just which part needs emphasizing clearly depends on the purpose of the job analysis. A careers master is concerned with general information about occupations; an apprentice supervisor needs rather more detailed knowledge of a smaller number of

jobs; and an engineer training capstan operators needs a highly detailed knowledge of the materials, tools and operations used in capstan work.

The importance of systematic job analysis is still not widely realized in industry in this country: *systematic*, for obviously job information is implicit in every employment officer's work. A substantial job analysis was, however, completed in the British Army not later than early 1942—involving in fact about 6,000 jobs. In America, Dr. Shartle, the Head of the Occupational Analysis Section of the Social Security Board, which has been responsible for occupational analysis on a large scale, stresses its fundamental importance; so also do American companies who have taken seriously the problems of selection. He points out the usefulness of job analyses, and of the classification of job analyses, made by his section in *e.g.* enabling the relation of army to industrial jobs to be perceived. This assists in allocating men to jobs in the armed forces and in placing men with army experience in industrial jobs.

Dr. Shartle mentions the value of job analysis training. "It has been found,"* he writes, "that by having trained job analysts in the local (employment) offices, it is possible to obtain more complete information from employers as to their hiring requirements and also to obtain more complete information from applicants. A person who has had job analysis training, even though that job analysis training is brief, finds out for the first time what that job really is. Our experience indicates that those employment interviewers who have had training in job analysis do a better job of interviewing, a better job of recording significant occupational information, and also do a better job in interpreting worker qualifications in terms of job requirements. I strongly recommend job analysis training for persons who do employment interviewing."

The (American) Dictionary of Occupational Titles uses a standard terminology and classification which the public employment offices throughout the country also employ. This enables them to find related jobs quickly.

One aspect in particular of job analysis calls for expert treatment—the description of the job in terms of abilities and skills that can be measured objectively. One British engineering firm says in that part of its brochure dealing with drawing office apprenticeship that: "a natural ability to visualize mechanisms and structures is a distinct advantage," but the question at once arises in selecting potential draughtsmen: "What is the psychological nature of the ability which is concerned with the "natural ability to visualize mechanisms and structures"?

Clearly, at this point, job analysis crosses over into the field of occupational psychology, and the further problem arises as to the manner of testing for the aptitudes, which with experience or training, will show themselves as the abilities necessary for the job. Ultimately, for the selection procedure, it will be necessary to know what sort of rating is required for different abilities, and the scores that correspond to them on the requisite tests.

RECRUITING AND TRAINING FOR SELECTION.

Only when a sound body of recruits is forthcoming can effective selection methods bear the greatest fruit. It is therefore important that all possible steps be taken to initiate and maintain a comprehensive recruiting policy. For example, steps should be taken to contact schools and the local juvenile employment officer in connection with the selection of boys as apprentices, or for work in the shops where they are potential apprentices. This does not mean merely writing a hurried letter once a year; it means having something suitable to offer, and then convincing schools and the juvenile employment officer of this.

* C. L. Shartle. "New Selection Methods for Defense Jobs"—Personnel Series No. 50. *Psychological Aids in the Selection of Workers.* American Management Association, 1941.

Visits to schools and universities are useful, and more might be done to encourage visits of masters and boys from schools to industrial concerns. Careers masters and headmasters, naturally enough, like to hear of the progress of their old scholars, and occasional discussions of successes and failures pay good dividends. They assist schools and the juvenile employment officer in their task of placing, and the company in its task of selection.

One engineering firm which had built up a good contact found, on analysis, that during a year 78 per cent. of boys were accepted who had been recommended by schools with whom contact had been maintained, 30 per cent. of boys who were already in the firm and who applied, and only 12 per cent. of boys who were the subject of the usual letter of application.

Bold and vigorous recruiting policies are necessary to attract a higher percentage of good material from the public and secondary schools to engineering apprenticeships, and to junior scientific positions within the industry.

It often happens that recruiting is from boys or youths or men with the company. For example, boys who have been in the shops since they entered industry at the statutory school leaving age may be considered at about 15½ to 16½ years of age for apprenticeship. It is necessary not only to ensure that an adequate percentage of these boys are of sufficient and suitable calibre for them to be potential apprentices, but that by various means active steps are taken to sort these boys out—by suitable tests, by continuous follow-up in the shops and in their studies and, of course, by the keeping of adequate records.

Here is the ideal state of affairs for good selection, for it is desirable that this should be a continuous process, and should not be confined to one report from the shops or to one sets of tests or one examination. The best results will be obtained when several filters are applied successively and independently over a period of time. This may be productive of good results even under difficult conditions.

In one aircraft firm it was rather felt that the acute shortage of boys, and the difficulties of travel consequent upon war-time dispersal would make allocation of boys to the jobs for which they were most suited out of the question. Nevertheless an experiment made in this connection not only provided most useful data, but gave valuable results even within these serious limitations, in enabling the most suitable boys to be recommended for training as toolmakers, for whom there was a great need, and for apprenticeship.

Incidentally, it also indicated in no uncertain manner the great assistance that suitable aptitude tests may afford, for it was possible to test 15 boys who had been transferred at the request of the toolroom foreman, or whom he had recommended for transfer from the toolroom, because they would never make toolmakers. A provisional classification into A, B, and C had been adopted, and 13 of these boys obtained grade C scores on the tests. Not one of them would have been recommended for toolroom work had the allocation procedure which was later adopted been in force at the time these boys were placed in the toolroom.

The development on sound and generous lines of pre-entry courses attracts more and better recruits, and smooths the transition from school to industry. They provide an admirable source from which data may be obtained which will be useful in any future selection and allocation. In this sense, they may be described as civilian "general service corps."

Anyone selecting apprentices should have a clear idea of the jobs to which apprenticeship of one sort or another will lead, and ought to have at least *some* idea of what the demands of the various departments are likely to be—the relative if not the absolute demands. This means that he should be brought in on any discussions affecting the present and future supply and allocation of supply of personnel. All too often, his sole information in this

direction comes from the head of a department who informs him over the telephone that he wants "an apprentice"—whether a short one or a tall one, not being stated!

This unsatisfactory state of affairs can lead to nothing but the third-rate results it warrants. A rota of senior members of the firm from which an advisory committee can be formed to assist on selection is sometimes a good thing, in so far as it shifts some of the responsibility for the material selected on to the heads of departments who will later train, or select from that material, and it may be conducive to a fruitful exchange of views.

The provision of University Vacation Courses may assist in building up a dossier of likely candidates and is bound, if these courses are well run, to provide more information on University men than can be obtained from a thirty minute interview, and a reference from their professor.

As industry rarely makes its requirements sufficiently known, the educationists usually get away with it! There seems to be a growing agreement nevertheless, that a period of at least a year is desirable in industry before a youth proceeds to a full-time engineering course. Arangements should be made during this year for the student to attend a local technical college for, say, one day a week. The University of Durham requires all engineering students to have had one year's experience in industry before proceeding to the second year course.

Post-apprenticeship and adult schemes need developing. Run effectively they can be extremely valuable. They may range from short refresher courses consisting of a few talks and perhaps a visit or two, to extensive full-time courses. They may take place in the parent firm or in other firms with whom exchanges can be arranged. But no matter where they take place, nor what their duration and nature, it should always be remembered that their object is to provide an incentive to those taking part to acquire fresh knowledge and experience, or to keep themselves up to date in their own field; to create a sense of movement in the company or group of companies; and to provide a pool of recruits for higher posts.

With regard to the first point, I should say that there is hardly a field of knowledge relevant to industry in which it shows so lamentably deficient a knowledge as that of incentives. There is too much of the "under the counter" method. It is essential that opportunities for such courses should be advertised openly throughout the company, and that plenty of effort should be called for in the conditions laid down for eligibility for them.

A small committee could do excellent work here—comprising, say, the general or works manager, a departmental head, and the person responsible for training—the training officer, head of the training department, apprentice supervisor, or whatever he may be called. The nature of the training concessions offered and the names of successful applicants should be made known by clock or departmental notices.

This sort of training should incorporate or involve a certain number of annual departmental moves. For example, a limited number of draughtsmen might be offered the opportunity of spending a year in the stress office or in the aerodynamic office, and *vice versa*. The usual objection to this is that the men who would most benefit by such an exchange, the best men, are those whom the departmental head can least afford to move. But the *apparent* loss of efficiency in moving a man who has become relatively proficient in one department, to another department of which he has no, or little direct knowledge, will be more than offset by the incentive offered all round to others, to become eligible to apply for the same concessions. This is a very real point.

The author was once informed that the effect of a number of bright apprentices, all in very active training—theoretical and practical—in a Drawing office was to stimulate the office generally and particularly the junior draughtsmen who could see themselves getting left unless they "bucked up their ideas." To

get the best results it is essential that nothing should be offered for nothing.

In this connection again, the keeping of sound records is highly important. If concessions such as ability bonuses, can only be offered to *some* of those eligible, the rest will be pretty well satisfied provided they realize that the most deserving individuals have been chosen. It is when the man who asks most frequently, or who is a favourite, gets the concessions that the rest are—not without reason—dissatisfied.

American literature on selection and training is unanimous in its insistence that the man responsible for training should be responsible directly to "top management." The interest of the management, and departmental heads too, is an important factor in training, and, through training, in selection for higher positions.

One admirable and indeed obvious form of training is the placing of juniors who appear suitable, as assistants to senior men. This never seems to have made much headway, partly perhaps because of the "indispensability" bogey. If the man's job is indeed so important, is that not all the more reason why he should not be the only one in the company to know something about it? Care is necessary in this form of training lest the junior becomes simply and nothing other than the senior man's office boy, and if training of this nature is to bear the maximum of fruit, the performance of each junior needs careful discussion and recording.

The methods of the admirable War Office Selection Boards will repay most careful study. No doubt the same will apply later to the Selection Board recently set up by the Civil Service Commissioners to examine candidates for the Foreign Service and for the Higher Grades of the Home Civil Service.

APPLICATION AND REPORT FORMS.

It has already been remarked that a careful job analysis in which the job is studied in detail and described in terms of the principal factors of success — ability, knowledge, character, skill, and physique—lies at the heart of all sound selection. Until this is done, how is it possible even to draw up a really good application form? Equally important is it that the selector shall continually exhibit a scientific attitude. How otherwise, having drawn up and used his application form, shall he be in a position to ascertain its value?

When the information desired has been decided on, the questions to be answered should be framed with great care (so that they may be answered easily) and in such a way that the answers are capable of exact interpretation and yield all the information on the point that is required. On one form appeared: "Games....." on which one applicant inserted "good" and another "football." Again, "Give your position in form in ...." (a number of named subjects) featured on a form of application for apprenticeship, but on only 70 out of 129 completed forms scrutinized, or 54 per cent., was it answered. It was later replaced by the following:—

> Put a circle round whichever of the letters: E (excellent), G (good), A (average), F (fair), P (poor) applies (or applied) best to your work in the following subjects. (Note.—If you are usually 1st or 2nd in a form of about **20** (*i.e.*, in the top 10%), mark yourself E; if you are usually in the next 4 (*i.e.*, in the next 20%), G. Similarly, if you are in the bottom 2 (10%), mark yourself P, and if in the next 4 (20%), F. If you are in about the middle (40%), mark yourself A; and similarly for forms of other sizes). If you have dropped a subject, write "D" against it. If you have never studied it, cross it out.
>
> **Arithmetic**: E G A F P **General Science**: E G A F P **Art**: E G A F P, etc.

The last thing in the world to do, in endeavouring to assess a candidate's school or departmental record, is to send out a letter asking for a "report." The reply is almost invariably as vague as the request. It is better to ask specific questions. The following are two extracts from a confidential form sent to the headmasters of boys applying for an aeronautical engineering apprenticeship in one company:—

1. What are his chances of passing School Certificate? E G A F P.
   What are his chances of gaining "credits" in *both* Science and Mathematics? E G A F P.
   What are his chances of gaining a "credit" in Art? E G A F P.
   What are his chances of gaining Matriculation exemption? E G A F P.
2. The following questions should be answered by the drawing of a circle round one or other of the five letters at the end of each. If the boy displays a characteristic to an outstanding degree, so that the answer to the question is definitely in the affirmative, encircle the a; if he fails conspicuously to display it, the e; if to an average degree, the c; otherwise the b, or d as appropriate. *A definitely affirmative answer should be indicated by the letter a.*

Would you call him a talkative boy? .... a b c d e
Is he polite and well-mannered in his general bearing? .... a b c d e
Is his general manner business-like rather than casual? .... a b c d e
Would you call him a popular boy? .... a b c d e
Does he tend to assume a position of leadership among any group of boys? .... a b c d e
If he is given a responsible task, does he usually perform it satisfactorily? .... a b c d e
Is he an energetic boy? .... a b c d e

Departmental report forms on which the assessor is asked to state whether certain factors such as attitude, ability, timekeeping, are "excellent," "good," "average," "fair," or "poor," are pretty well useless, even if they are accompanied by an explanatory note giving suggestions for grading, particularly with reference to their distribution. In any case the results need interpreting with care. As a simple example: the distribution of a large number of gradings of ability was 10 per cent. excellent, 35 per cent. good, 40 per cent. average, 12 per cent. fair, and 3 per cent. poor, *i.e.*, there were 45 per cent. excellent and good gradings, and 55 per cent. average, fair, and poor ones, roughly half and half. The uninitiated reading that a boy's report for ability was "good" would probably conclude that he was well up the list; actually all that can be concluded is that the boy is in the top half! Similarly, if a boy is graded as average, he is in effect, below average, *i.e.*, in the bottom half.

The type of report form advocated is shown overleaf, Fig. 2. Experience with it does not justify the obvious criticism that it is long. It is much easier to give a comprehensive report on a boy on such a report form than to begin *ab initio* to think what to say about him. My experience has been that the foremen and heads of departments using this form like it. The apprentice supervisor in another aircraft company asked his foremen and heads of departments what they thought of it, and they advocated its use.

The left-hand part of this form could be cut off and used as a master, the right-hand side only being sent to the foremen, etc., when the names of those to be reported upon have been filled in on the right-hand. Alternatively, the rating-scales, etc., corresponding to the left-hand of the form could be entered on record cards.

Periodic checks need to be made to ensure that a more or less normal frequency distribution is being built up of the gradings on each quality. It is also useful to study with particular care reports on boys who are unsatisfactory, because light may be thrown on *why* they are unsatisfactory. This information will obviously be valuable to the selector in his future work, *e.g.*, in his endeavour to ascertain during an interview to what extent the candidate before him possesses qualities that spell failure.

THE INTERVIEW.

The interview is the most usual mode of engaging personnel. It is also the most difficult part of the selection procedure to carry through well. Much time and thought are necessary to make it effective, though the weight to be given to it clearly depends on the

nature of the jobs for which selection is being made.

In an interview a rough idea can be formed as to the applicant's general level of intelligence, his knowledge and interests, and as to certain of his traits of temperament and character. It does, however, suffer, as the *sole* method of selection, from the fundamental drawback that a great many factors necessary for subsequent occupational success are simply not observable. For example, as aptitude for draughtsmanship is not closely associated with general intelligence, it cannot be assessed at an interview, no matter how skilfully conducted.

A further disadvantage of the interview is that the applicant is there with the idea of putting his best foot forward, and this is apt to colour the proceedings. One of the advantages of testing is that it enables applicants to be observed while their attention is occupied in working the tests.

The interviewer, having job requirements clearly in mind, will arrange the information he wants to record under a few main heads. The interview, however, should not be regarded as being mainly concerned with eliciting facts about the candidate's past experience. These should be known already from his form of application, and a check on them and further information have been obtained from the form sent to his last employer or school.

The interview should be concerned with eliciting the candidate's habitual attitudes, and so with creating an atmosphere favourable for the display of these. But a completed questionnaire provides a useful starting-point. The interviewer should keep himself in the background and let the candidate do the talking, if he shows himself willing to do so. His job then is to guide the canoe skilfully over the rapids. More frequently the candidate needs encouraging to talk.

As the selector is concerned to predict the future, a study of past as well as present indications is useful, a careful search being made for any *trends* in the applicant's development.

It is essential that the interview should be flexible. Without a doubt the best way to ensure this is for the interviewer to have a thorough command of all his resources, and for this reason the interview requires considerable preparation.

For example, suppose an interviewer habitually interviews boys for apprenticeship. He may decide to use an *interview record form*, and to arrange this under the following main headings: home circumstances ; physical characteristics ; test scores indicating general intelligence and special aptitudes ; entrance examination and school attainments ; games, hobbies and interests ; disposition; questions at interview; comments and suggestions.

He now needs to know *what* he is going to record under these headings, what questions he is going to ask or from what range of questions he is going to select to ascertain this information, and *how* he is going to record it. He cannot do better than write out a substantial number of questions, some easy to answer and some more difficult, and then memorize these thoroughly. He should avoid giving a lead in his manner of asking questions; should bear in mind that the indirect question, or the indirect approach, often yields the most fruitful results; and that "differential" questions are useful.

As an example of the indirect approach, suppose the interviewer wishes to ascertain whether the boy is really keen on becoming an apprentice, or whether he has been prompted to put in an application. He may be able to find out that the boy's father tends to decide things at home, and that the father regards the apprenticeship as a good thing. This gives him a useful lead, and enables him to infer what he probably would not be able to ascertain by asking a direct question.

The "differential" question tends to obviate the different standards adopted by different boys, and may elicit useful information as to the boy's bent. If the boy is asked whether

APPRENTICE TRAINING DEPARTMENT

From : APPRENTICE SUPERVISOR. *To :* Mr. .... *Dept.*

Date sent out ..... *DATE RETURNABLE* ..... *Date Returned* .....

APPRENTICE/SHOP BOY REPORT FORM

NOTES :

(1) Kindly complete the form *fully* and *frankly*. Do not " gloss over " bad or less attractive qualities or lack of ability, but record these frankly, as well as good points.

(2) Every effort is being made to reject boys who are unlikely to be really satisfactory, for reasons of ability, temperament, etc., and to select apprentices who are likely to be first-rate material. These forms, if carefully and honestly filled in, will assist a good deal to this end.

(3) Encircle the appropriate letter by reference to your experience of apprentices and other juniors of about the same age and experience who are now, or have been in your department.

(4) A copy will be sent for your retention if you wish and you will notify me to that effect.

(5) Suggestions for improving this report form will be welcomed.

(6) Kindly note that the report on each apprentice/shop boy should be initialled by the person responsible and the whole report should be countersigned by the foreman or head of department.

Copy Sent .....

AS A WHOLE, THE APPRENTICES IN THIS REPORT FORM ARE :

A	*Definitely good material*	**A** —	**Put a circle round whichever applies.** Take as your standard youths of about the same age who are doing, or have done work of a similar nature in your department.
B	*Satisfactory but not above average*	**B** —	
C	*Rather below average*	**C** —	

			JONES	SMITH	ROBINSON	ETC.								
KEENNESS AND APPLICATION— *Is he keen, interested and active to learn and does he apply himself or is he easily bored, or does he lack interest in his work ?*	(a)	Exceptionally keen and interested and eager to learn. Fully occupied with his work all the time.	a	a	a	a	a	a	a	a	a	a	a	a
	(b)	A good, keen worker and applies himself to his job.	b	b	b	b	b	b	b	b	b	b	b	b
	(c)	Generally shows interest. His application is neither better nor worse than that of most of the apprentices.	c	c	c	c	c	c	c	c	c	c	c	c
	(d)	Does not work as well as most apprentices. Rather easily distracted.	d	d	d	d	d	d	d	d	d	d	d	d
	(e)	His attention wanders and he does not seem interested in his work. Needs constant supervision to keep him at it. Lacks keenness.	e	e	e	e	e	e	e	e	e	e	e	e
CO-OPERATIVENESS— *Consider his ability to work with others and to carry out instructions. Is he obliging and pleasant to deal with? Does he co-operate willingly, or rather grudgingly?*	(a)	Always noticeably co-operative and willing to help in every way, and carries out instructions promptly.	a	a	a	a	a	a	a	a	a	a	a	a
	(b)	Distinctly co-operative. Carries out instructions promptly and willingly and is pleasant to deal with.	b	b	b	b	b	b	b	b	b	b	b	b
	(c)	Usually falls into line. Not particularly quick nor particularly slow in carrying out instructions and neither more nor less co-operative than most.	c	c	c	c	c	c	c	c	c	c	c	c
	(d)	Not very willing to carry out instructions or to co-operate generally and so inclined to be difficult to handle.	d	d	d	d	d	d	d	d	d	d	d	d
	(e)	Resents being given instructions and carries them out unwillingly. Makes no effort to do more than he can " get away with " ; generally is rather an obstructionist.	e	e	e	e	e	e	e	e	e	e	e	e
ACCURACY, CAREFULNESS AND FINISH— *Does he take every care to avoid errors or slovenly work, and does his work have a good " finish " ? Is it necessary constantly to check what he has done?*	(a)	One of the most careful apprentices I have known. Always checks his work and rarely allows errors or badly finished work to pass.	a	a	a	a	a	a	a	a	a	a	a	a
	(b)	May pass an error occasionally, but usually above the average for carefulness.	b	b	b	b	b	b	b	b	b	b	b	b
	(c)	About as careful as most apprentices. Average " finish " to his work.	c	c	c	c	c	c	c	c	c	c	c	c
	(d)	Allows a fair number of errors to pass and/or his work lacks " finish." Could be more careful.	d	d	d	d	d	d	d	d	d	d	d	d
	(e)	Careless and slovenly in his work, which often comes back to him because of errors, or has to be constantly checked.	e	e	e	e	e	e	e	e	e	e	e	e

F. HOLLIDAY

| | | |

he is "good at practical work" he will smell a rat and reply "Yes." Little useful information can be obtained by asking him whether he is good at theoretical work. But if he is asked to say whether he is better or worse at practical work of a mechanical nature than at theoretical work, irrespective of whether he may be good or bad at both, useful information may be obtained.

One investigator who related the replies of several hundred boys to this question to their test scores, found that those who said they were better at practical work than at theoretical work tended very markedly to have a better performance on the mechanical aptitude tests than on the intelligence test, and *vice versa*—this suggesting definitely that at any rate the aptitude tests he used did, in fact, measure mechanical aptitude over and above and distinct from, general intelligence.

The interviewer should develop the habit of listening, and be as passive an observer as possible; his idea is to try to see the boy as he is naturally, and to this end the boy should be encouraged constantly. Disapproval is the last thing that should be expressed. The awkward pauses that are in evidence in some interviews can best be avoided by the careful preparation advocated above.

Rating scales are a useful aid in interviewing. Consider for example: fluency of speech (*i.e.*, the extent to which the boy talks, regardless, for the moment, of whether he talks sense or not). Against this the interview record form may have the letters *a b c d e*, and the interviewer will encircle the *a* if the boy is voluble and really loquacious; the *b* if he talks more than most boys in similar circumstances; the *c* if he is about normal in this respect; the *d* if the boy needs encouragement to get him to talk; and the *e* if the interviewer finds it almost impossible to get the boy to talk.

By using rating scales for various characteristics, and suitably annotating them on the interview record form, the interviewer may record in an effortless manner that does not distract him from carrying on the interview smoothly, a whole wealth of information and a rapid pen picture of the boy.

Some interviewers use graphic rating scales such as the following, a mark being made along the scale to indicate the interviewer's assessment of the boy in respect of his ambition.

AMBITION.

Very keen indeed to succeed.	More than usually keen to succeed.	About normal in this respect.	Easily Satisfied.	Urge and Ambition noticeably lacking.

The interviewer may need to exercise adroitness in estimating the applicant's overall interview assessment from his various ratings. If the applicant shows a marked weakness in a particular direction which the job analysis and the interviewer's experience shows to be of especial significance, the interviewer will bear in mind that the strength of a chain is the strength of its weakest link.

Characteristics to be recorded during testing should be of occupational significance, relatively independent of one another, few in number and clearly definable. They should be *comparative*, and should be descriptively annotated.

Bearing in mind that in a "normal" group the distribution along a five point scale will be roughly 10, 20, 40, 20, 10 per cent., the best plan is to pick out the one, two, or three best boys in a group of about 20, for the particular quality under consideration and mark them *a*; similarly to pick out the worst one, two, or three boys and mark them *e*. The next best and worst three, four, or five, are then marked *b* and *d* respectively, and the remainder are *c*. Analyses in which observations during testing so recorded have been related to the subsequent assessment of apprentices show that they are of distinct value.

By referring back periodically to the inter-

view record forms of boys whom he has accepted as apprentices, the interviewer should endeavour to relate his overall interview assessment of them to the characteristics they later display, and to their subsequent success.

EXAMINING AND TESTING.

If this section on examining and testing is prefaced with the remark that in the whole range of education the art of examining is probably the most difficult, it is not because it holds such intrinsic difficulty, but because the difficulty is apparently so rarely realized. A student who has been given a redundant structure to stress, or a difficult mathematical problem to solve, recognizes the difficulty, realizing the value of knowledge, training and experience. But *anyone* thinks he can examine, *anyone* thinks he can test, *anyone* thinks he can interview—few indeed are those who realize that knowledge, training and experience are necessary here, too.

Whatever may be said of the advocates of psychological methods, one thing is certain. At least they have *some* appreciation of the difficulty of these things, and, as is evident in their published papers, at least they attempt in an unbiased, scientific manner to assess the relative value of different methods. This is more than can be said of their opponents, who are usually more concerned to air their own opinions than to examine the *facts*, and whose published results are conspicuous by their absence.

It is not sufficient for the selector merely to set an examination in his selection procedure. He should pay attention to the construction of the test, placing the questions in order of difficulty as found by a representative group of his examinees. He should consider whether his examination calls for a good sampling of the knowledge or ability to be tested. He should examine the spread of the marks and their frequency distribution; and above all he should relate performance in the examination to the subsequent success of the boys who took the examination.

Time is another factor to be considered. Why give a three-hour mathematics paper of the usual sort if analysis *proves* that a "new-type" examination lasting half-an-hour is just as predictive of future mathematical success? It may be that success at a particular examination or test bears little or no relation to subsequent success. In that case what is the point of it? A mathematics test given to applicants for trade apprenticeship, *i.e.*, to boys who were to become, and the majority of whom were presumably to remain, craftsmen, was heavily weighted with algebra; but to what extent is success at algebra related to subsequent success at craftsmanship? Very little, as a matter of fact.

Consideration should be given to the nature and form of the examinations chosen for any particular procedure. It is generally agreed by psychologists that the form of the psychological tests used should resemble the form of the material used on the job. The engineer, or would-be engineer, should be given performance tests, the clerk pencil-and-paper tests, and so on.

The unreliability of examinations of the ordinary sort contrasts sadly with the proved reliability of psychological tests. To mention but one instance: an investigation was carried out in which a pupil's paper in geometry and another in English were duplicated and sent respectively to 115 and 142 experienced teachers to be marked. The results were amazing. The marks assigned to the geometry paper showed a range from 28 to 92 per cent., while those from the English paper ranged from 50 to 98½ per cent. Psychological tests, being marked objectively, the marks awarded to a particular candidate by different examiners are all the same. Further, while there may be some increase in scores all round, the order of merit of a batch of candidates taking a psychological test for the second time will very closely resemble the original order of merit.

What used to be called "new-type" examinations have many advantages. They usually consist of a large number of short

questions—in this respect they are like psychological tests—which ensures a better sampling. They usually tend to distinguish the assessment of the candidate's basic *knowledge* from that of his ability to *apply* that knowledge, and they usually take less time—partly for that reason.

The general idea is to make an analysis of the material to be covered and, instead of asking longer questions, to break such questions down to their component operations, asking a larger number of short questions, each calling for only one component operation. As examples:—

(1) The idea of asking a student to evaluate

$$\sqrt[4]{.00007667^3}$$

is partly to see whether he can carry out multiplication and division involving the "bar rotation." This could be ascertained more briefly as follows:—

The logarithm of a number is $\bar{5}.8374$. Find the value of $\frac{3}{4} \times \bar{5}.8374$.

(2) A common National Certificate mathematics question is to give the candidate pairs of values of X and Y, to tell him that X and Y are connected by a law of the form $Y = aX^N$, and to ask him to ascertain the values of a and N by drawing a graph. To answer such a question takes the average student over half an hour. Much of the information which the examiner wishes to elicit from the candidate could be obtained in a few minutes by putting the question like this:—

X and Y are thought to be connected by a law of the form $Y = aX^N$. It is required to ascertain whether this is so, and in that case to find the values of a and N, by drawing a graph.

(i) What is plotted upwards? .....

(ii) To what base? .....

(iii) From the graph $a =$ .....

(iv) $b =$ .....

Analyses which the author has made on the results of new type mathematics tests suggest that they are as predictive as the more usual and much longer kind of examination, if not more. A few examples from a mathematics test set to grammar and public school boys applying for engineering apprenticeships follow:—

11. What is the area of the circle formed by trebling the radius of the one shown? .....
(a circle with "10 sq. ins." in it being shown).

12. What is the volume of the cube formed by doubling all the sides of the cube shown.....
(a cube with "10 cu. ins." in it being shown).

14. $X^{12} \div X^4 =$ ———

15. $\sqrt{49X^{16}} =$ ———

16. $\sqrt[3]{64X^6} =$ ———

17. If $X = 2$ and $Y = 3$ find the value of:

(a) $\frac{3X}{Y} + \frac{2Y}{X} =$ ———

(b) $\frac{Y^2 - X^2}{Y - X} =$ ———

18. Given $\frac{a}{b} = \frac{11}{2}$:

(a) $\frac{a + b}{b} =$ ———

(b) $\frac{a - b}{b} =$ ———

(c) $\frac{a + b}{a - b} =$ ———

35. Imagine you are provided with trigonometrical tables for angles up to 45° only. Say what you would look up in order to find:—

(*a*) sin. 65° ..... (*b*) cos. 50° .....

36. Write down the values (in terms of the trigonometrical ratios of angles which you can look up in tables) of:—

(*a*) sin. 135° ..... (*b*) cos. 150° .....

37. (*a*) write down the sine rule for solving triangle ABC:

(*b*) The sine rule may be used given .....

(*c*) The sine rule may also be used given .....

One mark was given for each correct answer, the maximum possible marks being 60.

There seems to be some misunderstanding regarding what are unfortunately termed

psychological tests, many people criticizing them as if they thought that the questions involved were rather slick inspirations. On the contrary the position is that much research has been carried out on test questions of different kinds. In intelligence tests of the verbal variety, to take one instance, there is widespread agreement as to the types of question which involve a high intelligence-content in their answering. *Analogies* are such a type, as for instance: *Fear* is to *anticipation* as *regret* is to: memory, hope, sorrow, hate, forget (the candidate being required to underline the correct answer).

Much learning involves the perception of relationships and analogies. For instance, the binomial theorem has been established by a teacher, and the expansion (*b*) of $(1+x)^n$ (*a*) has been written on the blackboard. The student is asked to write down the expansion (*d*) of the binomial $(1-3x)^4$ (*c*). To do this he needs to perceive the relevant relation of $(1-3x)^4$ to $(1+x)^n$, *i.e.*, to see that, if $(1-3x)^4$ is written as $[1+(-3x)]^4$, then it is in the same form as $(1+x)^n$. The rest is pure analogy. What expansion (*d*) will bear the same relation to (*c*) that the given expansion (*b*) bears to (*a*)?

Solving $\int \frac{dx}{\sqrt{3-4x-11x^2}}$, given the standard integral $\int \frac{dx}{\sqrt{a^2-x^2}}$, is similar.

The restricted use and development of trade tests in this country is surprising: they have a future. Trade Tests were developed in the U.S.A. during the War of 1914-1918, and the Occupational Analysis Section has since developed them for over 130 occupations. They may be of four kinds—oral, picture, written, or performance. The fundamental assumption underlying the first three—one that experience and analysis shows almost invariably to be justified—is that the knowledge which the test assesses is only acquired in the course of learning the trade, and therefore, that the extent to which a man can answer the questions correctly is a measure of the extent to which he has acquired trade skill.

SELECTION OF APPRENTICES AND DRAWING OFFICE TRAINEES.

In this section, a few of the methods evolved and the results obtained in an investigation into the selection of trade and engineer apprentices are considered. Since the selection of boys who will ultimately make successful draughtsmen and technicians has been for some few years of particular interest to the aircraft industry it is this problem which is particularly referred to here.

About 100 existing apprentices were given a verbal intelligence test in September, 1938, as well as a number of aptitude tests designed to assess mechanical aptitude generally and aptitude for reading and making drawings in particular. Further groups of apprentices were tested, and from January, 1940, to July, 1945, inclusive, all applicants for both trade and engineer apprenticeships, or a total of about 700 boys, mostly between the ages of $15\frac{1}{2}$ and $18\frac{1}{2}$ years. This was apart from about 150 boys in the shops who were not apprentices.

The company with which these boys were employed, or to which they were applying for apprenticeship, has its own technical school recognized by the Ministry of Education and the Institution of Mechanical Engineers for the award of Ordinary National Certificates in Mechanical Engineering. Facilities for pursuing the Higher National Certificate in either Mechanical or Production Engineering are available at a nearby Technical College. On an average there were, at any one time, a total of about 170 apprentices between the ages of 16 and 21, the overriding majority of whom were pursuing Ordinary and Higher National Certificate Courses.

The investigator, who was an instructor in the works technical school from November, 1936, onwards, and apprentice supervisor and head of the technical school from January,

1940, until July, 1945, taught apprentices mathematics and engineering science in the part-time day and evening classes provided for them. Works and departmental reports were obtained quarterly on all apprentices as well as reports from the instructors in the technical school. The investigator's predecessor—the then apprentice supervisor—furnished special reports on groups of apprentices, and one of his colleagues graded substantial groups of apprentices in December, 1942, December, 1943, and December, 1944—the trade apprentices on the basis of their present and anticipated shops proficiency, and the engineer apprentices as potential professional engineers.

As their engineering drawing instructor—and he was an experienced draughtsman—he graded classes of apprentices for their proficiency at (*a*) engineering drawing as such; (*b*) the design problems inherent in more advanced engineering drawing; and (*c*) the combination of these weighted in the proportion deemed appropriate to the particular standard of the drawing under consideration.

Constant visits were paid to works and technical and other departments in the course of supervision, and a considerable amount of information was obtained in all sorts of ways. Systematic schedules of detailed works training were adhered to pretty well throughout the investigation, and the investigator was thoroughly familiar with the academic and works progress of every apprentice. It would be very difficult to imagine any similar scheme in which it was possible for the investigator to have a better knowledge of the apprentices who were the subject of his investigation than this intimate and closely knit one.

There was, throughout, plenty of scope for apprentices, and there was much upgrading to the various drawing offices, the stress office, the wind tunnel and aerodynamics office, to flight observation, to the mechanical test, estimating and planning departments, and so on. This meant that there was a good deal of incentive to apprentices to do their best, and opportunity for them over a wide range of jobs to show what they could do—important points when one is concerned to relate their apparent intellectual and aptitude "ceiling" to their "ceiling" of performance in the works, in their studies, and in the various departments such as those mentioned.

All test scores were recorded on a chart—the intelligence test scores on the left-hand half, and the total score on the aptitude tests on the right-hand half. In each case there was a vertical scale which was *not* linear. (In a normal distribution there will be more scores near the middle than the extremes. Consequently to prevent overcrowding near the middle it is advisable to use a larger scale there.) Each apprentice tested was represented by a horizontal ink line two inches long against which his name was printed. A space was left to the right of this column of lines so that the scores of applicants could be indicated by a pencil line one inch to the right of the ink lines. In this way the names of applicants and their scores stood out quite clearly, and the relation of their scores to those of existing apprentices was apparent at a glance. Various percentiles and averages were marked by horizontal lines. This chart is mentioned for two reasons. In the first place, such a chart is to be recommended highly for practical use. Secondly it needs emphasizing perhaps that it was not a question of simply pulling out of a drawer otherwise unused lists of test scores in order to make periodic analyses. A continuous running check was made possible throughout the investigation by this chart, which enabled the investigator to visualize where each apprentice's test scores lay in relation to those of his fellows. In all matters relating directly to apprentices' progress this picture was clearly in his mind.

For example, an apprentice's examination results would come to hand and the investigator would at once conjure up the position of this apprentice on the chart of (*a*) intelligence test scores and (*b*) aptitude test scores. That the boy had obtained a distinction in

mathematics, but had failed in engineering drawing would register in the investigator's mental vision no more strongly than the significant fact that he was very high on the intelligence test and low on the aptitude tests. Another apprentice's excellent ability for toolmaking, together with his slow and halting ability at his studies, would at once call forth a picture of this boy as being low on the intelligence test, but distinctly high on the aptitude tests. And so on. The chart has, in fact, been invaluable.

Has the introduction of psychological tests, a broader recruiting policy, new-type tests, and a thorough follow-up of apprentices, produced better results? The answer given on all sides is definitely in the affirmative—by the works, the various technical departments, and the local Technical College where apprentices pursue Higher National Certificate Courses. Two foremen of important shops who volunteered the information that they had not had a dud sent them for over three years, and that the percentage of really good boys had shown a considerable and consistent increase, may be cited as examples. Great satisfaction has been expressed with the apprentices sent to the Drawing Office.

The investigator's predecessor made a detailed comparison between the examination results obtained in the external, approved National Certificate course examinations in 1939 by the company's apprentices, and by candidates from the rest of the county. The apprentices' performance was slightly superior. Subsequent similar analyses show a consistent gain in the extent of this superiority, until in 1944 the performance of the company's apprentices was about 50 per cent. better than that of the candidates from the rest of the county. This improvement was obtained despite the most unfavourable conditions—dispersal over a region where travelling facilities were bad, two evenings' overtime each week to 7.30 p.m., etc. This means that during the *six* years of war, successes were obtained that would previously have been obtained in *nine* years.

In September, 1944, 37 per cent. of apprentices were pursuing advanced courses of study, *i.e.*, Higher National Certificate or Endorsement, or final degree courses. Such a high percentage would normally *not* be desirable—it would indicate an ill-balanced scheme—but in view of the shortage of technicians, etc., a high proportion was much needed. Such a figure gives some idea of what can be done in a very short time. There is no doubt that from the point of view of examination successes, the scheme was exceptional. In particular, the investigator was recently studying examination figures of another similar company which offered much better facilities: there was no comparison.

Over 85 per cent. of the company's engineer apprentices selected by the methods advocated in this paper have passed straight through their course of study and obtained Ordinary National Certificates at a first attempt, after having been placed in the *second* year of the course immediately on entry to the company. The percentage of engineer apprentices passing the S.2 engineering drawing examination—boys, it should be noted, who had not studied the subject before, and were brought up to S.2 standard in one session—was of the same order. About 75 per cent. go straight through to a Higher National Certificate and obtain one at a first attempt, almost the whole of the balance of 25 per cent. passing at a second attempt.

Numerous analyses have been made to investigate the relation between scores on the verbal intelligence test used, on the aptitude tests taken separately, and on the total score obtained on the aptitude tests on the one hand, and examination marks in different subjects on the other. Groups were treated separately, year by year, and correlation coefficients calculated. Larger groups were formed by combining smaller groups of apprentices who had sat for the first time for particular examinations.

For example, all apprentices who had sat for the S.2 examinations for the first time in

1939, 1940, 1941,* were combined, and placed in an order of merit on the intelligence test. There were 65 of them, of whom 33 passed in all three subjects. Twenty-two of these were above the half-way line on the intelligence test; there were 11 of them in the top quarter on the intelligence test, as against 5 in the bottom quarter. Over 75 per cent. of those gaining distinctions (15 out of 21) were above the half-way line on the intelligence test.

All apprentices commencing in, say, the second year of the National Certificate Course, were placed in an order of merit on their scores in the different tests, and analyses were made to investigate the fertility of the top and bottom halves and the top and bottom quarters of this list in providing future successes at higher academic levels. Orders of merit on the tests were also related to subsequent examination marks by the method of correlation.

"Critical score analyses" were made with a view to finding what minimum admission scores were desirable for subsequent examination success. The method used may be illustrated by an example, Fig. 3. Each cross in the figure represents an apprentice, and shows, against his intelligence test score, whether he subsequently passed or failed in the first year National Certificate Course examination in mathematics. It will be seen that 84 per cent. of those passing had previously scored 90 or higher on the intelligence test, whereas 76 per cent. of those failing had scored less. An admission score of 90 would thus have been sound on an average in 80 per cent. of cases.

Figures for average agreement as thus obtained were worked out for admission scores over the whole range of usability of the test, and graphs drawn of average agreement to a base of admission-score. This was carried out for all apprentices taking S.1, S.2, and S.3 National Certificate Course examinations in (i) mathematics and (ii) engineering drawing, from 1939 to 1944 inclusive, and for all the tests used. *In every case* the intelligence test gave a better agreement than the total score on the aptitude tests in predicting subsequent success at mathematics. On the other hand, the aptitude tests, taken separately (and the total score on the aptitude tests) gave a better prediction of success at engineering drawing than the intelligence test.

This is unequivocal proof of the unique value of aptitude tests in predicting ability at engineering drawing, for the value of intelligence tests in predicting general academic success has been shown, not only in this research, but in numerous others. *It is not possible to predict a boy's engineering drawing ability from the level of his general intelligence.*

It would be of great value if tests—of the trade test variety—were devised for assessing ability to *read* engineering drawings. Analyses made in this investigation suggest that the aptitude tests which were proved to be useful in predicting ability to *make* drawings, are also useful in predicting ability to *read* drawings—an ability of wider significance in engineering.

A number of different kinds of analyses were made over some years, covering a substantial number of groups of apprentices to investigate critically the value of psychological tests in predicting "apprentice ability" generally. Two different criteria were adopted, one for the trade apprentices and one for the engineer apprentices. All the evidence pointed to the aptitude tests giving a distinctly better prediction than the intelligence test in the case of the trade apprentices, whose present and estimated shops proficiency alone was the criterion of success adopted.

It is not possible to predict a boy's practical engineering ability from the level of his general intelligence. Or, to put it another way: it is proved to be more reliable to predict a boy's practical engineering ability from his scores on certain psychological tests of "mechanical aptitude" than from his score on a verbal intelligence test of proven value.

* Unfortunately more up to date figures are not to hand.

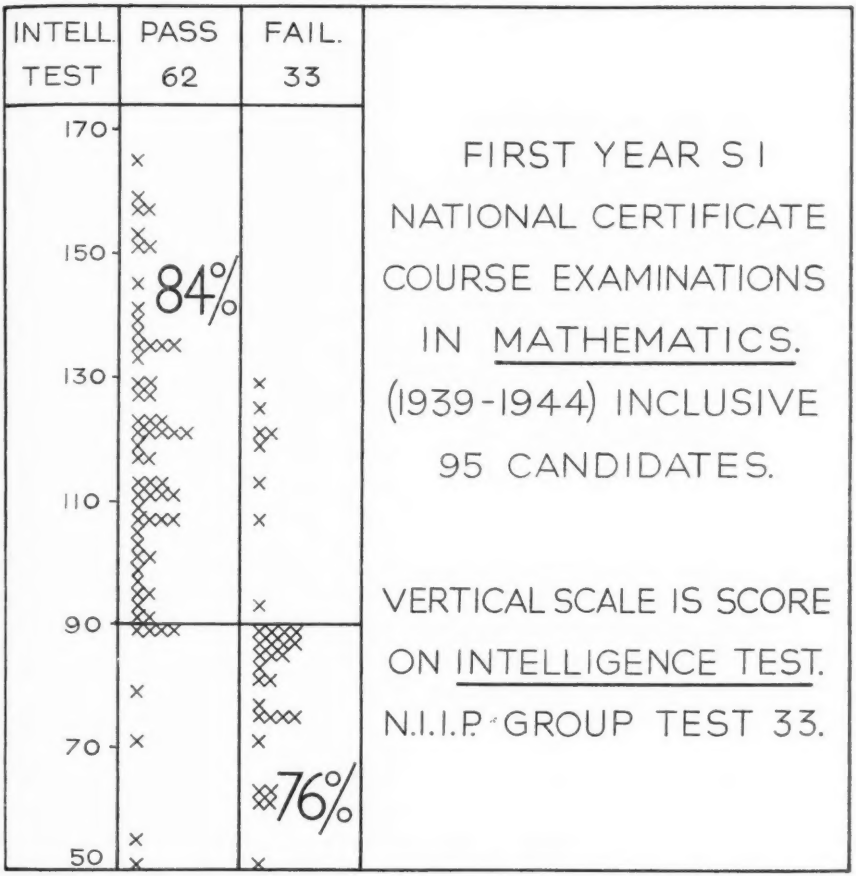

Fig. 3

Cases of agreement between psychological test scores and subsequent success were much more numerous than those of disagreement, but a careful study was made, in every analysis carried out, *of all cases of disagreement*. This showed that particularly useful or adverse traits of character were nearly always responsible for the disagreement. In most of the remaining cases subsequent experience, up to a maximum of six years, indicated that the assessor's estimate was at fault. The balance was infinitesimal.

A forecast was made in September, 1938, after the investigator had no more knowledge of about 40 trade apprentices than he could glean from half a day's testing, of their future academic success, a five-point scale, excellent, good, average, fair, and poor being used for this purpose. A copy of this was sealed and handed over to the then apprentice supervisor. A study of it seven years later, in the autumn of 1945, leaves no doubt as to the prognostic value of psychological tests.

Long-range studies of this description are invaluable. It is to be hoped that experimental psychological testing will be carried out in

* National Institute of Industrial Psychology.

large Technical Colleges where four or five parallel S.1 classes exist. After all, such research would commit them to nothing. It would merely be necessary to give the tests, mark them and then relate the test scores to the subsequent examination successes of those tested.

A procedure was evolved for sorting out the boys entering the author's company and, among other things, a careful analysis was made as to the distribution among the grades into which they were placed on entry of those subsequently applying for releases. The grades were: A—very much above average, potential apprentice; B—would probably make a skilled craftsman; C—very unlikely to become skilled; and D—unsuited for engineering. It transpired that 20 per cent. of releases applied to D boys, whereas only 11 per cent. of boys had then been graded D. On the other hand, although 51 per cent. of boys had been graded A or B, only 42 per cent. of releases applied to them. Nearly twice as many boys whose psychological test scores indicated that they were unsuited for engineering were applying for releases as might have been expected !

No matter how the data is studied—and there is much of it, and it has been surveyed from many angles—the value of psychological tests as important aids to more effective selection and allocation stands out clearly.

SOME FURTHER POINTS.

There are those who fear the use of psychological tests, criticizing them for not being able to do what they make no pretensions to do. This is rather like criticizing a stethoscope on the grounds that it cannot possibly detect colour-blindness! It should be stressed that it is often not possible to tell whether a particular test is predictive merely by inspection, and that training is necessary for all who wish to use the methods and apparatus of industrial psychology. The inertia of the hard-boiled does nothing like as much harm as the enthusiasm of the half-baked. Not for nothing did that superb intellect Nietzsche remark that: "The first adherents of a creed prove nothing against it"! Beware, therefore, of being what the Americans call "over-sold."

The difficulty—and it is a question that is always being raised—is how and where can training be acquired? The only answer, to the author's knowledge, is: by means of a short course lasting ten days or so and conducted by the National Institute of Industrial Psychology, or by a Diploma Course in Industrial Psychology. Large companies having employment officers, training officers, etc., can solve this problem easily, but it was estimated before the war that 53 per cent. of our factories employed less than 250 people. No doubt many of these were engaged on engineering, and the organization of problems of selection and allocation in such small factories is difficult. It might be that their needs would best be served by the occasional visits of a consultant, or by their sharing a trained man with other local, small firms. A number of education authorities employ psychologists and while they are usually educational rather than occupational psychologists, their help would be useful. Why should industrial concerns not approach the education authorities along these lines?

It would, of course, be particularly in the interests of small firms that there should be set up machinery for the giving of sound vocational guidance on a nation-wide scale. It is up to the representatives of industry on Juvenile Advisory Committees to press for effective action.

The value in terms of human happiness of adequate vocational guidance and selection is immense. "Nobody," wrote a doctor in the press recently, "who has had much experience of nervous troubles can help observing that one great cause of them is maladjustment. The square peg in the round hole represents the greatest single cause of neurotic trouble in modern life." The bogey of the opposition that the use of psychological methods is alleged to call forth, is sheer rubbish within the author's seven years'

experience of using them. Time and time again both parents and boys have shown their appreciation of his efforts to get the square peg in a square hole.

Brigadier J. R. Rees has stated that figures collected in connection with War Office Selection Boards, from failures as well as successes, show that 90 per cent. of men who were considered by them think they have had a square deal. He also pointed out that officer wastage was cut down by the W.O.S.B.s from something between 20 per cent. and 30 per cent. to 3 per cent. Large groups of about 5,000 men were asked their opinion of the army system of selection: 85 per cent. were quite enthusiastic about it. Indications from smaller groups showed that 80 per cent. of the men would appreciate vocational advice on leaving the army.

It is true, however, that a rose under another name may smell even sweeter, as is shown by the great popularity of T.W.I. (Training Within Industry), which is nothing more and nothing less than pure Industrial Psychology!

There is one important aspect of work of this nature which has not been mentioned so far—that of fitting the job *to the individual*. Much remains to be done to this end in the way of motion study, involving, for example, the more effective placing of material, and in design of machinery. The motor car manufacturer does not select people who can drive his car—he designs his car so that almost anyone can drive it.

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A paper entitled "Selection of Staff by means of Intelligence and Aptitude Tests," by R. C. Woods and A. S. MacDonald (*The Journal of the Institution of Electrical Engineers*, April, 1944) gives some interesting examples of psychological test questions, and describes work which has been in progress in a light electrical engineering factory for some years.

The latest report, dated November, 1944, of the lengthy investigation carried out by E. Patricia Hunt and Percival Smith for the Birmingham Education Committee, "Scientific Vocational Guidance and its value to the choice of employment work of a Local Education Authority," needs mentioning. The admirable manual for employers issued by the Ministry of Labour and National Service in July, 1943, entitled "Training New Entrants to Industrial Work," refers to the importance of carefully allocating new recruits to the courses for which they are most suitable, and states clearly the principles upon which training schemes must be based if they are to be effective. The best manual on the subject.

The selected annotated bibliography, "Employment Tests in Industry and Business," issued by the Industrial Relations Department of Princeton University, New Jersey, certainly deserves to be mentioned, as also does an article by F. I. De La P. Garforth, "War Office Selection Boards (O.C.T.U.)," which appeared in the April, 1945, issue of *Occupational Psychology*.

The author may perhaps be forgiven for referring here to a paper of his entitled: "A Survey of Selection and Allocation for Engineering Occupations," since this was an attempt to bring to the notice of engineers a good deal of the literature dealing with the subject. It appeared in the March, 1943, issue of the *Journal of the Institution of Production Engineers* and gave a substantial number of references. A later article —"The Relation between Psychological Test Scores and subsequent Proficiency of Apprentices in the Engineering Industry"— appeared in the October, 1943, number of *Occupational Psychology*, the Journal of the National Institute of Industrial Psychology, Aldwych House, London, W.C.2, and is obtainable as a reprint. A further one—"The Boy and his Job: an Industrial Effort"— appeared in the issues of *The Engineer*, dated October 19th and 26th, 1945.

DISCUSSION.

THE PRESIDENT was particularly interested in the author's association of aptitude and intelligence in regard to draughtsmanship. It would appear, he said, that more aptitude and less intelligence was required; in the paper it was stated: "For example, as aptitude for draughtsmanship is not closely associated with general intelligence, it cannot be assessed at an interview, no matter how skilfully conducted." That seemed to make matters difficult for the Chief Draughtsman when selecting his personnel.

MR. F. H. M. LLOYD (Hawker Aircraft Co. Ltd., Associate Fellow) congratulated the author on a very interesting paper. He was interested in the economics of running such a scheme as had been outlined. What was the number of staff required to look after such a scheme, to collect and collate all the various reports and records, and how did that number compare with the total number of employees in the organisation concerned? He also asked how long the scheme had been in operation, and whether as a result of it the quality of the entrants to the drawing office had improved vastly over the quality of the entrants prior to the introduction of the scheme.

In the past the selector had been usually an engineer of wide experience. Hence, the selection of personnel for design had frequently been the prerogative of the Chief Designer or some senior person on the design side deputed by him. By experience, the selectors had learned how to interview and they had become skilled psychologists. Many people who applied for entry to an organisation on the design side did not come through an apprenticeship scheme; in such cases one had to rely on the interview and had to decide where references were misleading.

Commenting that the health aspect of the problem had not been stressed sufficiently in the paper, he said it was of no use engaging brilliant men if their health were such that they were frequently away because of illness.

MR. E. DUCKETT (Vickers-Armstrongs Ltd.). He had had experience with Mr. Holliday at the time of the change-over, when the psychological tests were introduced, and could confirm their real value. Even if their value was doubted on the positive side, the unsuitable applicants could be weeded out with a fair measure of confidence. It was possible under the old scheme, by interview and by checking up on academic attainments, to select a youth of high intelligence and a good social background, who was fired by enthusiasm and interest. Yet after a lapse of a few years it had been found in some cases that something was missing, namely, that quality of being able to visualise things in three dimensions, which could be definitely measured by the aptitude test.

In addition to the interview in the old selection method there was the probationary period in the shops for, say, six months. When the type of work that was given to the new apprentice was realised it was appreciated that his faculties were not extended in any way, so that the probationary period in the shops did not bring the selectors any nearer to a solution. Drawings in orthographic projection were the basis of most discussion and activity in any of the technical offices, which meant that that visualising power was very necessary.

Intelligence and aptitude could be measured and interpreted in terms of suitability for a particular job. A further factor, which was not so easily measured, was that of temperament. It was appreciated that during an interview an applicant would put forward his best arguments; further, school reports could be unreliable. Thus, there was a certain amount of risk in trying to assess temperament on the basis of an interview and school reports. Temperament, of course,

worked both ways, hindering those who were bad tempered, petulant or unco-operative, whereas it helped those with determination and the capacity for sustained effort.

Confidential school record forms, in which a series of definite questions were asked, formed part of the Vickers-Armstrongs scheme, and he thought that they should be used to the full, because they enabled a quality to be measured which could not be measured by the ordinary tests. If a score could be obtained and interpreted, well and good; but to get the immediate reaction of an applicant to a hypothetical set of conditions was admittedly rather difficult.

Again, great care must be taken to check on health; in some cases 50 per cent. of a boy's time had been lost through illness.

For the selection of trade apprentices the same procedure was adopted, involving tests, interviews, etc., in order to get the right combination of qualities. Something more was needed in those cases, however, for it was too much to expect to differentiate between a good sheet-metal worker and a good skilled machinist and turner by such means. The only solution there was to have the boys in the apprentices' workshop, which was independent of production and where an applicant could be placed for final allocation after a period of, say, six months.

The aptitude tests, however, did give a definite pointer as to whether an applicant was best fitted for occupations such as pattern making, the work of fitter-erectors, etc. The workshop could be used subsequently for periodic courses to teach craft, instead of just leaving young people to pick up information as they proceeded. The instructors in the workshop would be chosen, of course, for their ability to pass on their knowledge and skill.

Now, more than ever before, it was in the national interest that every youth entering industry should have a reasonable chance of success. Mr. Holliday had made a useful contribution to that end by following up his tests with investigations and checks, both in the factory and in the classroom, and proving the value of his tests by subsequent performance.

MR. R. McCRAE (Head of the Engineering Department, Kingston Technical College). He had been in a position to assess the results of Mr. Holliday's method of selection. Mr. Holliday's students came to the College for the last two years of their Higher National Certificate courses, and he could say unhesitatingly that the measure of success attained by those apprentices was far higher than that attained by any other group in the district. He could thoroughly recommend that method of selection to anyone about to modernise.

MR. J. A. C. WILLIAMS (Associate Fellow) said that surely all modern psychological thought was towards the end that psychology, *i.e.*, the working of the mind and character, was bound up with physiology. Probably with regard to Mr. Holliday's tests that was not so immediately apparent; but on the whole character of a man, surely physiology had a great effect. He believed that the American Army had a separate section of the Medical Service dealing with what was called psychosomatic medicine. The experts in that section definitely sized up a man's character and mind and thus were able to reduce the amount of disease in respect of such things as duodenal ulcers. Again, surely some slight physiological defects must be related to defects in the mind.

The people mainly referred to in the paper, who had come under Mr. Holliday's immediate jurisdiction, were trade apprentices and draughtsmen; but he would like to know whether such work as that described was being used to cover such people as engineering salesmen and managers. There was considerable movement among various sister institutions to further the cause of the engineer as a manager, and it seemed that there were many mind qualities which came into a manager's build-up more than into the build-up of the ordinary technical assistant.

Mr. Holliday's work was most important at the present time because in the educational institutions there was a terrific shortage of teaching staffs; the greater the degree of correlation that could be secured at the beginning in selecting apprentices, the greater would be our success in building up after the war as the teaching potential would be used to the greatest advantage.

Presumably Mr. Holliday's work on the selection of apprentices had been concerned wholly with boys. He asked whether he had had experience of the selection of women for various types of work and whether he expected any difference in the results.

Contributed. After hearing the discussion on the paper he wished to suggest that physio-psychological selection was carried out by the types of personal interview; in these the mental attitudes or character of the applicant was assessed. The training period for the applicant was the adolescent period in his physical life. Adolescence was a period when unpredictable physical changes occurred and he suggested that injustice was sometimes done by such changes occurring, with a consequent alteration in the mental "build-up." It was doubtful whether such injustice could ever be overcome because of the very nature of the trouble. Any single basis of selection was incomplete; all that could be hoped was that employers would keep as virile a type of mind as Mr. Holliday had shown in achieving practical results of real worth, without a claim to infallibility.

CAPT. J. LAURENCE PRITCHARD (Hon. Fellow, Secretary of the Society). The paper had dealt, quite rightly, with Mr. Holliday's own experience. But he would like to have seen some comparisons made with the experience in America, where quite a lot of intelligence testing had been developed.

One matter which had not been mentioned in connection with the aptitude and intelligence tests was the assessment of the time required by each individual to answer questions. Some boys were careful, would think for a considerable time and give the right answers; others would reply quickly and might or might not give the right answers. He was not sure that a boy who could give an answer quickly was quite as good, especially for the Aircraft Industry, as one who required a longer time, but who eventually made up his mind and gave the right answer. He would like to know whether a note was made of the time required for answering.

A class of people whom he regarded as being more important than any other in the Industry, but who apparently were not catered for, were those who were to become research workers. He asked whether Mr. Holliday had done anything to cater for them.

Giving his own experiences as a member of a Committee concerned with choosing engineering apprentices for scholarships, he said that of 60 boys who were chosen for scholarships over a period of five or six years, their general age being 15—16½ years, 59 had been absolutely successful. The boys were later trained to take the Higher National Certificate, and then were posted to the drawing office, the production department or any other part of the works for which they were suited.

Discussing the method of choosing the boys, he said they were required to give their complete school records, and normally it was essential for them to hold the School Certificate. The Committee looked at the Certificates in order to see whether the credits obtained were of the right kind, which meant mathematics, chemistry, physics and that kind of thing, and above all English. If a boy had secured credits of the right kind, he was asked to attend for an interview which was carefully staged to put the boy completely at his ease. The Committee had before them his school record, the facts concerning his home life, his position with his parents, whether they were fairly well-to-do, and so on.

He felt that perhaps a little too much re-

liance might be placed on aptitude and intelligence tests; it was necessary also to assess personality, at which it was difficult to arrive. One year, for example, the Committee to which he had referred had interviewed a number of boys and had asked each of them what he would do if he were not selected for a scholarship, it being pointed out that only a few were available.

One boy had replied that, even if he were not selected for a scholarship, he was still determined to get into the Aircraft Industry. It was pointed out to him that that would be difficult without a scholarship, because most of the firms could not take apprentices at the moment; and every difficulty was put in his way. But the boy had persisted and had said that, even if he had to begin by serving cups of tea to the workmen, he would get into a works, for he was convinced that, once he was on the floor, he would get away with it.

On the other hand, another boy, who had impressed the Committee as being very intelligent, quick and confident, had said that if he could not get a scholarship he could get a job in his father's office. He did not get a scholarship.

MR. R. H. SANDIFER (Handley Page Ltd., Fellow), supporting Captain Pritchard's remarks, said that the tests described by Mr. Holliday were of great value, and the analyses must have occupied some time. If that were all justified, then there was justification for appointing, not just one selector, but a committee of selectors, representative of all branches within the organisation. The candidates should be interviewed, or rather "met," by the committee in an informal way, as mentioned by Captain Pritchard.

There was one doubt in his mind about the combined scientific and psychological approach discussed in the paper; he felt that quite a number of people in the Industry might not co-operate to the fullest extent. The scheme was a little elaborate; for instance, there were five gradings—"excellent," "good," "average," etc.—and they might easily be condensed to four. Many people might co-operate in the wrong way unintentionally.

Putting in a plea for consideration of the reverse of that which had been discussed, he said they had been talking about the interviewer or interviewers sizing up a boy from the point of view of his ability to become successful in engineering; but what about the boy deciding whether engineering would be a suitable career for himself, not from the point of view of making money, but from the point of view of whether he would be happy and interested, and therefore, a probable success?

If the Industry could provide facilities for students who were still at school, preferably in their last year, to visit the works so that they would have a better understanding of what was in store for them and could appreciate the scope of the work and what was expected of them, they would respond to the various tests much more readily. They would also benefit if at their schools they were visited occasionally by people within the organisation of industry, who would discuss with them various points concerning the Industry and the careers of those engaged therein.

MR. PETER CRAWLEY (Handley Page Ltd., Student), speaking from the point of view of one who had been selected, said that he felt flattered by Captain Pritchard's picture of the success achieved subsequently by the group of S.B.A.C. scholarship holders—unless he were the odd one to which reference had been made!

Commenting on Captain Pritchard's views concerning the method of choice, he said the school record could be obtained from the school and it was straightforward. The home record was perhaps not so satisfactory as an indication of a boy's home life; and he had gathered that it was considered rather from the point of view of economics.

Discussing the interview from the point of view of the unfortunate persons being interviewed, he said they were treated in a manner which gave them every confidence, so that they could be natural and could put their best foot forward. He could vouch personally for the efficacy of the preliminary discussion on films, rugby or any other such subject, and of the methods adopted by the selection committee. He hoped Mr. Holliday would give his views on the relative values of that method of selection and the method which he had adopted.

As a corollary, the scheme put forward by Mr. Sandifer for the appointment of works committees to select a wider body of men for the Industry had much to commend it. But who would select the members of those committees? It was not a job which anybody could do; either the members of the committee were scientific selectors or they were picked at random, perhaps because of their machine shop skill. In the latter case it was felt that they might not make good selectors.

The arrangement of works visits for boys at school who were keenly interested in engineering was of great value. Again, in assessing the results achieved by an apprentice after he had been selected, and his general ability, the keenness which he was able to sustain was of fundamental importance. In that connection he recalled that his first six months in the Aircraft Industry were misery, because he had not the slightest idea that he was working on aircraft. He might have been making something for a kitchen range. It was of great importance that aircraft apprentices should know that they were becoming aircraft engineers, and not just any old kind of engineers. To most apprentices "aircraft" meant more than "engineering."

Asking how Mr. Holliday assisted the development of the characteristics of the men as they progressed further up the scale after selection, he said the draughtsmanship aptitude tests might be set possibly to indicate whether or not a boy was suitable to become a projective draughtsman. But, as he saw it, very little aircraft draughtsmanship was of this type. Did Mr. Holliday's tests for draughtsmen show whether they would make good aircraft draughtsmen or good projective draughtsmen? The latter would appear to be the case, since Mr. Holliday took as the basis of comparison a drawing examination which could be no more than a test of projective skill.

The series of tests used so far by Mr. Holliday did not appear to cater for the selection of two important groups, future managers and research workers; could the series of tests be amplified for that purpose or should different methods be used from the outset?

MR. I. O. HOCKMEYER (Associate Fellow), dealing with vocational selection, emphasised its importance and pointed out that few people had the opportunity to choose their jobs in life. Even fewer had the opportunity to visit works beforehand and to see the carrying out of the jobs they were intending to do, so that they had not the faintest idea of what those jobs involved. For instance, illumination might appear to be interesting, but illumination work in the laboratory could be dull.

The Army tests during the war had proved that the psychological selection of vocation was very useful. In the case of certain tests which were set by the Army, the results had been discussed with the candidates afterwards. Did Mr. Holliday apply that practice in the factory?

Recalling the paper dealing with psychological methods which had been read to the Institution of Electrical Engineers, and asking whether there was a "child's guide" to psychological testing, he said there was a persistent fear of psychology as being something dangerous, it being forgotten that every approach to every human being in the course of life required some practice of psychology. He asked whether any firm

could suddenly embark on the business of psychological testing, or whether it was necessary to engage specially trained staff from outside, and probably from a very limited source.

Discussing interviews, he said that one firm had sent a selection committee to various colleges in the area of their works to select students who were to be offered appointments at the works. Those on the short list were invited to visit the works for a period of two days. The first day was devoted to a tour of the works, which were very large, so that the candidates could see what an engineering works looked like; and during the second day the candidates were interviewed by members of the selection committee. They were submitted to individual tests.

He personally had been asked by one member of the committee how he would travel to the works, and he had replied that his father would buy him a car. The next question was whether he would prefer a motor bicycle, and there had followed a discussion on the merits of motor bicycles and cars. In that sort of atmosphere one felt very much more at ease than in circumstances where you were asked two or three technical questions, and if you did not know the answers it was concluded that you did not know anything.

Examinations were generally recognised as the principal method of assessing a candidate's abilities. Written examinations were nowadays not regarded as the best criterion of ability but at the moment a better method was not known. Mr. Holliday, however, had used them as a standard of reference for the newer form of psychological testing.

MR. R. R. HOPKINS (Vauxhall Motors) referred to one of the charts showing the results of aptitude and intelligence tests and asked what was meant by the author's statement that the curves were "weighted."

Also, were all the aptitude tests of the pencil and paper type, or were there also tests of a practical type?

His firm had had an engineering apprenticeship scheme in being for 30 years. There were now about 150 apprentices in the main scheme and another 150 spread over 14 departmental schemes. The boys were selected by interview by a committee, which was appropriately informal. The matters taken into account were school records, character, and what he would call "motivation," *i.e.*, the boys were asked why they wanted to come into the business, and what they would do if they were not selected.

The percentage of failures had been very small. But the Company felt that they would not keep abreast of the times, that they would not be making every possible endeavour to get the right people, unless they studied testing technique and progressed still further with selection procedures.

He believed the answer to the question concerning the selection of men for managerial posts was largely that, if the very best trainees and apprentices were chosen in the first instance, there would probably be available in years to come a good grade of people from whom to choose potential managers. But if in the first place we applied only a fairish or tolerably good method of training, it might not throw up the top-notch people in the years to come.

All boys employed at Vauxhall Motors went into training at the age of 16 years, but many were taken from school at the age of 14 years. The latter were selected with a view to having good candidates for an engineering or departmental apprenticeship scheme at the age of 16 years; so that the sieve applied to boys of 14 years was very fine. Before the boys left school the Company obtained not just their school reports but individual reports for each of the boys from the master. Two papers were set, one being very similar to the N.I.I.P.33, and the other having a mathematical bias. The boys were also interviewed and were examined by the works doctor.

Interview by committee might not be the ideal form of interview, but committees were valuable in deciding how to place the various boys; it was most helpful to have a committee of three or four men discussing which boys should be admitted and which should not.

He asked for Mr. Holliday's comments as to whether, after testing the boys at the age of 14 years, they should be re-tested at the age of 16 years.

Explaining that he and his colleagues were present at the meeting because they wanted to know more about the aptitude testing business, he said they believed it was sound; but they were a little nervous, realising that, as Mr. Holliday had so aptly put it, less harm was done by the dead-heads than by the half-baked enthusiasts. For more than a year they had visited various firms on the matter, and they learned a great deal from the Army; a great deal of assistance could be obtained from the War Office. They had visited primary training centres and had seen the selecting procedure for the ordinary intake; they had seen the sieve operating for officers, and the experiments with selection tests which took into account intelligence, aptitude and other matters, such as temperament.

It was realised that schemes could not be evolved overnight, and if they could get a scheme in operation within 18 months they would consider they had done well. They had much enjoyed the paper, and were most grateful to the Council of the Society for having given them the opportunity to be present.

MR. J. H. LOWDEN (Associate Fellow) suggested that the Aircraft Industry would not be served best by merely selecting the salt of the earth and keeping them for a future date, and he asked for more information concerning the subsequent training.

MAJOR G. P. BULMAN (M.A.P., Fellow) asked, assuming that the tests for intelligence and aptitude were used, so to speak, as "go" and "not go" gauges, how the "victims" reacted, for it was important that, whatever system of selection was applied, a candidate who had failed should feel that he had had a square deal. Were efforts made to convince him as to why he had failed?

FLIGHT-LIEUT. ANDERSON (Associate Fellow), recounting some of his experiences during a visit, with colleagues, to the works of the Lockheed Aircraft Corporation in the United States, said that they had submitted themselves to the psychological tests which were applied there. Two tests were made at the works, one psychological and the other an intelligence test. The psychological test was based on temperament, the considerations being whether the applicant was of a type who would work well with other men; whether he was willing to take orders; whether he was well disciplined; and whether he was of the engineering type, and so on. For example, a candidate was asked whether or not he admired a thief who had made a daring escape, and whether he would prefer that the thief should be brought to justice; many men were escaping from prisons in the United States at that time.

After the test, the psychologist prepared a graph based on the number of marks gained for engineering ability and the other attributes. The examiner had pulled him up on one question, suggesting that from his reactions it appeared that he had not answered quite fairly; the examiner had added that from the answers to other questions he could prove the type of man he was, and he had said what type he was!

The examiners were specialists employed by the various firms, and they were 100 per cent. for the firms. They always did justice to the firms, and admitted that they might do an injustice to a candidate's abilities, if there were any injustice at all.

After the candidates were selected, the Company insisted on their continued training. After attending school for training in

leadership, etc., apprentices were re-examined for technical knowledge and also were re-examined by the psychologists. They underwent psychological and intelligence tests, the latter bearing more on the mathematical side, and there were also questions on aircraft engineering.

Those who applied for higher posts, such as those of departmental managers, and so on, or whose claims were being considered, were subjected to psychological tests. In one such case he and his colleagues were allowed to remain in an adjoining room in order to hear the questions put to a candidate; they were afterwards told that the applicant was not appointed to the post.

The Lockheed Company relied on psychologists' reports, having proved to their own satisfaction that such tests did give a satisfactory selection. In future, clerks and the men at the benches would be selected and graded.

MR. HAROLD KENDALL (Bristol Aeroplane Co. Ltd., Associate Fellow). *Contributed.* Mr. Holliday, in his paper, had provided some tabulated results of the use of The National Institute of Industrial Psychology tests in selecting personnel. Among those taking part in the discussion were some who took their stand in the opposite camp, holding the view that a good interviewer, armed with the necessary data as to educational background, could obtain similar results. As, however, no detailed results were quoted, the following extract from records in The Bristol Aeroplane Company's Drawing Office Training Department might prove interesting for comparison.

When, in 1943, it was decided to introduce draughtswomen into the Drawing Office, a number of girls were selected for training.

The educational standard required was that of School Leaving Certificate with credits in mathematics and science. Selection was by interview somewhat on the lines of that mentioned by Captain Pritchard, where, in the earlier part of the interview, subjects such as sport, hobbies, music, pictures and wireless programmes were discussed and the applicant encouraged to express her opinions and to give reasons for the views expressed. A short General Knowledge Test (written) and an Elementary Mathematics Test were completed by the applicant after the interview.

Altogether 50 applicants were selected for training and the following results were obtained:—

To Drawing Office (Aircraft) ...	29
,, Research Dept.	3
,, Flight Test Dept. (Instrumentation Analysis)	2
,, Air Ministry Publications (Preparation of Diagrams)	2
,, Amendments Section	3
,, Jig and Tool D.O.	1
,, Special Duties	2
Total	42

Of the remaining eight, who were counted as a loss, three left the district, three were released on domestic grounds, and two left to take up other work.

In five of these cases no objection was raised against the application for release as it was doubtful if they would have reached the standard of work required. The other three had made average progress up to the time of their release and would, in all probability, have made good. On the other hand, three of those who completed the course were only passed as fit for amendment work and therefore there were eight who did not come up to expectations, thus giving 84 per cent. successful selection.

Last year 10 of these girls were allowed to take the S.1 Mechanical Engineering Course at the local Technical College and eight passed the terminal examination. One of the two who failed missed the examination in two of the four subjects because of illness, but passed in the other two subjects, Practical Mathematics with 81 per cent. and Engineering Science with 88 per cent. On the basis of her half term results she could have

been expected to have passed in the other two subjects, and so they might be justified in claiming 90 per cent. successful selection.

He would like to add that, while permission has been given to quote the above figures, the trend of thought indicated in the above remarks was not necessarily that of the Company, and these figures were given merely as a concrete example for comparison with those given by Mr. Holliday.

He would like to add his thanks to Mr. Holliday for a very interesting paper.

MR. HOLLIDAY'S REPLY TO THE DISCUSSION

The President. With regard to the association of aptitude and intelligence, he had shown that the draughtsmen needed a certain aptitude; that did not mean that the draughtsman did not need intelligence. If he were to be engaged on design, obviously he would need a good deal of intelligence; but he would still require that aptitude, and inasmuch as it was not closely associated with intelligence, it could not be assessed by an interview.

Mr. F. H. M. Lloyd. About 120 boys were examined each year, and no extra staff was engaged for that purpose; the Supervisor could do the testing, and with the aid of a clerk he could keep the records.

The scheme was started experimentally in the autumn of 1938, and was used for the practical selection of personnel from January, 1940; in July, 1945, to his knowledge it was still in operation, and he believed it had continued to date. There was no doubt that the quality of the personnel engaged had improved very much indeed since the scheme was adopted.

Mr. E. Duckett. The extent of the follow-up in the scheme was very considerable; in some cases it had extended from prior to 1938 until July, 1945. Eight years was a fairly long time. If one started with a boy 16 years old, then by the time observations on him had finished he was 24 years old.

With regard to the health of applicants, he had rather implied that that was looked after very carefully. There were difficulties occasionally; he recalled a case where a boy, although he had said that he had no tendency to fits, had suffered one in the machine shop. Where it was thought necessary, applicants should be referred to the Works doctor, or to their own doctor, or to an optician.

Mr. J. A. C. Williams. If a boy were intelligent he would not necessarily become a manager ultimately for that reason; if he were not intelligent, he certainly would not become a manager—at least, he hoped not. He stressed that tests occupied only a minor place in the scheme. Certain character traits were very important indeed. On several occasions he had recommended his Company to accept for apprenticeship boys whose abilities appeared to be only mediocre, because these boys appeared to possess leadership or "guts" to an unusual degree.

Captain J. L. Pritchard. Generally speaking, he did not think that it would be satisfactory to select boys at school. A selector needed to have knowledge of the individual on the one hand, and knowledge of the job on the other hand, and then information was needed to enable the selector to marry the two. Schoolteachers generally lacked knowledge of the job, and engineers a knowledge of the individuals; each had their share to contribute.

With regard to the time which a boy required to answer a question, he said one could not deal with the matter adequately within the compass of a few words; but the time factor was *not* the most important point of a good psychological test. Intelligence tests had been devised in which there was no time limit. Was it better to have a boy who was a little slower than another, if he were more sure? Every time. One could help to assess carefulness or lack of accuracy by recording test errors as well as test scores.

A boy who scored 60 and made only 3 errors was much better than a boy who scored 70 and made 30 errors ; the first was fairly sure, whereas the other was very inaccurate. By examining test errors in relation to test scores one could assess their value, and he had met some very illuminating cases during the past eight years.

Very little had been done, within his knowledge, concerning the selection of research workers, except by intelligence tests. A research worker, of course, must be intelligent ; on the other hand, an intelligent man would not necessarily become a good research worker.

A point which he emphasised was that the results which had been shown to the meeting were obtained from groups of apprentices who, during a careful selection procedure, had themselves been interviewed, had completed a carefully designed form of application, and who had been the subjects of a " school record form " sent for completion to their schools. Nevertheless, the tests still differentiated the members of each group *inter se*.

Mr. R. H. Sandifer. The method of inviting boys to visit the works while they were still at school was a good one, and he was much in favour of it. The method of what might be called " trial-situations " was being adopted quite a lot. It had been used by O.C.T.U., where the Officer Cadets lived-in for two or three days and joined in all the activities. It was obviously better to select over a period of three days than three hours.

Mr. Peter Crawley. It was difficult to answer the question as to whether selection by a committee was preferable to selection by an individual. Could there be informality in a committee ? He would not try to answer that question, because he was not a psychologist ; but generally speaking, he felt that it was very much more difficult to ensure informality in the case of a committee than in the case of an individual, provided, of course, that the individual was a suitable person.

So many people imagined that selection consisted of picking out the boys who attained the highest scores. But in fact the jobs for which boys had to be selected were not always suitable for those who had attained the highest scores. There was the story of the Company that claimed great success with psychological tests. Applicants who passed the tests were rejected ; those who failed, accepted ! That might prove sound. It was not wise to select a clever boy for a job which offered no outlet for his intelligence. Each job needed intelligence and so on *within a given range.*

Mr. I. O. Hockmeyer. In his opinion scores obtained in the tests should not be discussed with boys. If a boy were told that he was very intelligent, he would sit back and say, " I could—if I wanted to "! On the other hand, if a boy were dull, no good would be done by telling him so ; the result would merely be to damn him. He never discussed scores with individuals, and he believed that that policy was in accord with the general opinion. However, attempts would be made to persuade a boy to accept an opinion, if it was founded on a sound basis. For various reasons boys had been sent to him as apprentices after he had recommended that they should be turned down, and in almost all cases they had been unsuccessful.

The results of external approved National Certificate Course examinations represented a criterion of success, but it was not the only one.

Mr. R. R. Hopkins. If a boy obtained a 30 per cent. mark on the intelligence test and a 70 per cent. mark on the aptitude test, his final score would be 50 per cent. if the two scores were equally weighted. If more weight was to be given to the intelligence test, then his final score would be lower than 50 per cent. It was possible to determine what weight should be attached to each to give the best prediction of success.

All the tests were of the pencil and paper type. It must not be thought, however, that he advocated only that type of test. For adequate reasons it was decided to continue with the type of test with which the scheme was started, the best results being obtained by means of a follow-up lasting for some years.

Referring to managerial appointments, he said that the Lockheed Aircraft Corporation claimed, after some years of experience, that they were very successful in selecting future managers. Their selection programme was on a very extensive scale.

With regard to re-testing, he did not think any sound selector would suggest that a selection procedure should be confined to a short period of time; successive filters should be applied over a period of time. The problem still remained that if there were 50 applicants for 10 jobs, it was still necessary to select the most suitable ten.

Major G. P. Bulman. Dealing with the question as to whether the candidates, after having been interviewed and tested at the works, felt that they had had a square deal, he said they certainly did. Of over 850 boys whom he had tested, he could only recall one who did not think much of his selection procedure, and this boy had been recommended for acceptance (against Mr. Holliday's better judgment) by reason of the long service rendered to the Company by a relative of the boy. Most of the boys had made the point that the selection was made very carefully. Many parents, whose boys had been turned down, had written to express appreciation of the care taken in dealing with their sons' applications.

THE PRESIDENT urged that it was necessary to make the engineering profession and industry very much more attractive to the majority of the rising generation, to make them feel that in the engineering industry there was a great future for them. There was a tendency for a great deal of our young brains to go either into politics or finance in this country, and in America they tended to go into business. Presumably that was why we had such good politics and the Americans had such good business !

As to whether or not psychological examinations would indicate the suitability of individuals for particular jobs, he said that in engineering and science, generally speaking, it was the practice to consider examination results. While examination lists might indicate the academic attainments of the examinees, they did not necessarily show whether a man was fitted to be a manager, or a draughtsman or a designer. It would be interesting to carry out a series of these psychological tests on the whole staff of a Company at selected dates, say, once in every two years, and to note how the various individuals responded, for it must be remembered that the people who made up an engineering staff were not static. They were growing plants, and the flowers they bore depended to some extent on the atmosphere in which they lived and on the kind of mental food they were given while they were growing in mental stature. It would be interesting to deal with a cross-section first at the top ; then one could form an idea as to whether Mr. Holliday's " gadgets," which were moved up and down, really did select the right men for the right jobs.

Perhaps in his earlier remarks he had unintentionally cast a slur when comparing aptitude with intelligence. The aptitude to do a given job successfully was even more important than intelligence, if one rated intelligence as the ability to answer certain questions and perhaps achieve success in an examination. Aptitude for a given job meant a natural ability to do it, a natural ability to see the solution of a given problem ; intelligence refined or polished it. Thus, if one considered aptitude in that sense, it was not quite right to speak of a draughtsman as a person of lower intelligence !

Commenting on the author's reference to incentive, it was terribly difficult for people who were engaged on a job which had con-

tinued over a long period, and which had involved a lot of dull and dreary and humdrum work, to retain incentive. To stand before a board, 4′ × 3′, covered with white paper, and to watch the number of lines gradually increasing and getting themselves into an ordered pattern, was very boring. It was necessary to keep a person's incentive and interest in that particular job, and Mr. Holliday was right in emphasising the importance of that matter. The President quoted from the paper the comment : " The inertia of the hard-boiled does nothing like as much harm as the enthusiasm of the half-baked."

Finally, proposing a hearty vote of thanks to Mr. Holliday, he advised that the paper was worthy of careful reading, for it contained some most illuminating and interesting ideas.

THE AUTHOR'S SUMMING-UP

In investigating the value of a selection procedure or of its components it was necessary to show that a good standard of recruit was selected. But this was not sufficient. It was necessary further to follow-up those selected, to obtain estimates of their occupational proficiency and to show that the component parts of the selection procedure, and the selection procedure as a whole correlated significantly with those estimates, *i.e.*, that they would differentiate those selected *inter se*. This was what the author had been carrying out over a long period.

For example, it had been asserted, no doubt quite rightly, that the board-interview method of selection used for the selection of S.B.A.C. scholarship winners had, in fact, selected a good type of boy. But the sceptic (in the other camp !) might assert, as he had every right to do, that this good standard might simply be due to the rather unusual type of boy applying ! Only boys with just that little bit more interest and " guts " would apply for such a scholarship, or would be recommended by their schools to apply.

To produce evidence that would hold water it would be necessary for the interviewing committee (a) to classify the successful candidates on, say, a five-point scale (relatively excellent, good, average, fair, poor); (b) to obtain *reliable* estimates of their occupational proficiency on the same five-point scale; and (c) to demonstrate the significant relationship between the two. When, and only when, there was a (statistically) substantial measure of agreement between these two sets of gradings would there be scientifically acceptable evidence of the value of the committee's work. This was the sort of thing that researchers into selection methods were engaged on doing.

The ideal, of course, was a straightforward statistical comparison of all possible components of a selection procedure—no mean job ! Where psychological tests had been compared with other aids to selection (and no one knowledgeable had ever claimed they were anything more), they had more than borne the comparison. The Birmingham researchers, for example, compared (a) psychological test scores and (b) the ordinary entrance examination marks of boys entering a junior technical school, with estimates of the boy's proficiency in engineering subjects at the conclusion of the two-year course. The psychological tests gave a better prediction than the entrance examination.

To employ psychological tests as " go " or " no-go " gauges would be to misuse them crudely ; though to flaunt the " danger " of psychological tests because they might be so used was palpably unfair. A mathematics test might be so used, or any other test, or an interview ; they frequently were !

The cost of initiating a testing programme might be quite modest and the benefits con-

siderable. No doubt the initial services of a consultant in this field could not be obtained much more cheaply than those of a consulting engineer, but when once a suitable member of the Company's staff had been trained, the cost of the selection procedure might be negligible.

This was a field of knowledge rather off the beaten track for engineers, but its literature was worth careful study.

Finally, it must be emphasised that it was, largely, a field of *scientific* knowledge—with all that that implied—and chiefly, that all opinions and hypotheses needed testing *experimentally*, and that all terms ("success," etc.) needed defining exactly.

THE ROYAL AERONAUTICAL SOCIETY

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RESPONSE IN YAW

by

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SUMMARY

If the motion of an aircraft is restricted, near the ground, to zero bank, comparatively simple solutions to the resulting equations of motion can be obtained, enabling the response to an applied yawing moment to be calculated rapidly. In this paper the analysis is made for three simple forms of applied yawing moment. From the results obtained in a particular case it is possible to judge the suitability of the fin and rudder design chosen on the basis of maximum sideslip reached. A general curve of overswing, in terms of the aerodynamic derivatives of the aircraft, enables the maximum sideslip to be calculated rapidly in a particular case.

Because of typographical difficulties the symbols ^ have been replaced by ° with v, r and t throughout the paper.

1.0. INTRODUCTION

Current developments in airworthiness requirements have focussed attention on the response of an aircraft to the sudden cutting of an engine during take-off. The safety of the aircraft in these circumstances depends, among other factors, on the maximum angle of sideslip reached, with or without corrective action by the pilot.

The necessity for meeting these safety requirements has led to a need for a rapid method of estimating this maximum sideslip and other characteristics of the subsequent motion, in the initial design stage, when fin and rudder size are otherwise undetermined.

This paper presents a suitable method which requires for its use a knowledge of the ordinary stability derivatives of the aircraft. It is felt that reasonably accurate estimates of these derivatives can now be made without tunnel tests on the particular aircraft concerned.

The analysis is restricted, for simplicity, by the assumption of zero bank throughout the motion, and that the rudder is held neutral until corrective action is taken. This implies that the pilot has sufficient aileron power at his disposal, and applies it continuously in order to keep the bank zero.

2.0. ANALYSIS

2.1. *General*

Restricting the motion to zero bank, we can write

$$\left.\begin{aligned}(D+\bar{y}_v)v^\circ \qquad +r^\circ &= 0\\ -Nv^\circ+(D+n_2)r^\circ &= C_n\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where $D=\dfrac{d}{d\tau}$ and the other nomenclature is due to Mitchell (Appendix I) the equations being valid if the product of inertia terms can be neglected.

Eliminating r° we have

$$\{\, D^2+(n_2+\bar{y}_v)D+(n_2\bar{y}_v+N)\,\}\, v^\circ=-C_n \quad . \quad . \quad . \quad . \quad (2)$$

Solutions of this differential equation will now be found for the cases

(a) C_n independent of τ

(b) C_n a linear function of τ

2.2. *Constant applied yawing moment*

The solution of (2) can be written in the form

$$v^\circ=v^\circ_s+e^{x\tau}K\cos(y\tau+E) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where

$$v^\circ_s=-C_n/(n_2\bar{y}_v+N)$$

and $x\pm iy$ are the roots of the auxiliary equation

$$m^2+(n_2+\bar{y}_v)m+(n_2\bar{y}_v+N)=0 \quad . \quad . \quad . \quad . \quad (4)$$

given by

$$\left.\begin{aligned}x&=-(n_2+\bar{y}_v)/2\\ y&=\pm\sqrt{\{(n_2\bar{y}_v+N)-x^2\}}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

whence, incidentally, we have

$$n_2\bar{y}_v+N=x^2+y^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Now

$$\frac{dv^\circ}{d\tau}=Ke^{x\tau}\{x\cos(y\tau+E)-y\sin(y\tau+E)\} \quad . \quad . \quad . \quad . \quad (7)$$

Initially, when $\tau=0$, $v^\circ=\dfrac{dv^\circ}{d\tau}=0$ . . . . . (8)

$$\therefore\ x\cos E=y\sin E$$
$$E=\tan^{-1}x/y=\varepsilon_1 \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Also

$$v^\circ=0=v^\circ_s+K\cos E$$

$$\therefore\ K=-v^\circ_s\sqrt{(x^2+y^2)}/y=-\kappa_1 v^\circ_s. \quad . \quad . \quad . \quad . \quad (10)$$

The complete solution is thus

$$v^\circ=v^\circ_s\{1-\kappa_1 e^{x\tau}\cos(y\tau+\varepsilon_1)\}. \quad . \quad . \quad . \quad . \quad (11)$$

Substituting for v° in the first equation (1) we have

$$r^\circ=-(D+\bar{y}_v)v^\circ$$

whence we have the solution for r° in the form

$$r^\circ=-v^\circ_s[\,\bar{y}_v-\kappa_1 e^{x\tau}\{(x+\bar{y}_v)\cos\overline{y\tau+\varepsilon_1}-y\sin\overline{y\tau+\varepsilon_1}\}]. \quad . \quad . \quad (12)$$

From (11) and (12) we see that the solutions for v° and r° represent damped oscillations if x is negative, that is if

$$n_2+\bar{y}_v>0$$
$$i.e., \quad n_2>-\bar{y}_v$$
$$-n_r/i'_c>y_v$$

Now n_r can be written

$$n_r=n_{r0}-ln_{vF} \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where n_{vF} is the fin contribution to total n_v, l is the fin arm in terms of the semi-span $b/2$, and n_{r0} is the value of n_r when n_{vF} is zero. Thus the oscillations are damped if

$$(ln_{vF}-n_{r0})/i'_c>y_v \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Hence the minimum size of fin is given by

$$ln_{vF}>i'_cy_v+n_{r0}$$
$$n_{vF}>\{i'_cy_v+n_{r0}\}/l \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Differentiating (12) we have

$$\frac{dr^\circ}{d\tau}=v^\circ_s.\kappa_1e^{x\tau}\left\{(x^2-y^2+x\bar{y}_v)\cos\overline{y\tau+\varepsilon_1}-(y\bar{y}_v+2xy)\sin\overline{y\tau+\varepsilon_1}\right\} \quad . \quad (16)$$

$$=0 \text{ for } r^\circ \text{ maximum or minimum.}$$

The condition for r° maximum or minimum is thus

$$\tan\overline{y\tau+\varepsilon_1}=(x^2-y^2+x\bar{y}_v)/y(\bar{y}_v+2x)$$
$$\tau=\frac{1}{y}\left\{n\pi+\tan^{-1}\left(\frac{x^2-y^2+x\bar{y}_v}{y(\bar{y}_v+2x)}\right)-\varepsilon_1\right\} \quad . \quad . \quad . \quad . \quad (17)$$

whereas the condition for v° maximum or minimum is

$$\tau=n\pi/y \text{ from (7)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Thus the maximum and minimum values of r° are displaced in time from those of v° by an amount $\Delta\tau$ given by

$$\Delta\tau=\bar{\varepsilon}_1-\varepsilon_1/y \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where $\bar{\varepsilon}_1=\tan^{-1}(x^2-y^2+x\bar{y}_v)/y(\bar{y}_v+2x)$

This displacement is of importance when a plot of r° and v° against time is required.

2.3. *Time linear applied yawing moment*

Writing $C_n=C_{n1}\tau/\tau_1$
the solution of (2) becomes

$$v^\circ=\frac{v^\circ_{s1}}{\tau_1}\left\{\tau-\left(\frac{n_2+\bar{y}_v}{n_2\bar{y}_v+N}\right)\right\}+e^{x\tau}\,K\cos(y\tau+E) \quad . \quad . \quad . \quad (20)$$

where $v^\circ_{s1}=-C_{n1}/(n_2\bar{y}_v+N)$

The initial conditions being given by (8), then

$$\frac{dv^\circ}{d\tau}=\frac{v^\circ_{s1}}{\tau_1}+Ke^{x\tau}\{x\cos(y\tau+E)-y\sin(y\tau+E)\}=0 \quad . \quad . \quad . \quad (21)$$

and

$$v^\circ=-\frac{v^\circ_{s1}}{\tau_1}.\frac{n_2+\bar{y}_v}{n_2\bar{y}_v+N}+K\cos E=0 \quad . \quad . \quad . \quad . \quad . \quad (22)$$

Now

$$(n_2+\bar{y}_v)/(n_2\bar{y}_v+N)=-2x/(x^2+y^2)$$

Writing

$$K=\kappa_2 \cdot \frac{v^\circ_{s1}}{\tau_1}$$

Then

$$2x/(x^2+y^2)=\kappa_2 \cos E \quad . \quad . \quad . \quad . \quad . \quad (23)$$

and from (21)

$$1=\kappa_2(x \cos E - y \sin E) \quad . \quad . \quad . \quad . \quad . \quad (24)$$

Solving (23) and (24) for κ_2 and E we have

$$E=\tan^{-1}(x^2-y^2)/2xy=\varepsilon_2 \quad . \quad . \quad . \quad . \quad . \quad (25)$$

and

$$\kappa_2=1/y. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

whence

$$\kappa_2 \cos \varepsilon_2=-(n_2+\bar{y}_v)/(n_2\bar{y}_v+N)$$

The complete solution thus becomes

$$v^\circ=\frac{v^\circ_{s1}}{\tau_1}\{(\tau+\kappa_2 \cos \varepsilon_2)-\kappa_2 e^{x\tau} \overline{\cos y\tau+\varepsilon_2}\} \quad . \quad . \quad . \quad . \quad (27)$$

From (1), we have, again

$$r^\circ=-(D+y_v)v^\circ$$

which becomes

$$r^\circ=-\frac{v^\circ_{s1}}{\tau_1}[1+\bar{y}_v(\tau+\kappa_2 \cos \varepsilon_2)-\kappa_2 e^{x\tau}\{(x+\bar{y}_v) \overline{\cos y\tau+\varepsilon_2}-y \overline{\sin y\tau+\varepsilon_2}\}] \quad . \quad (28)$$

2.4. *Changes in applied yawing moment*

When a change in the form of C_n takes place at a time τ' after the commencement of the motion, it is convenient to consider the original motion to continue, and to superimpose a new motion on it, starting at τ'

For $\tau<\tau'$ the solutions derived above for C_n constant or linear apply.

For $\tau>\tau'$ when there is a new yawing moment C_n' applied instantaneously at τ', the secondary (additional) motion is given by an equation of the form of (11), with C_n' substituted for C_n and $\tau-\tau'$ for τ, that is, for example

$$v^\circ=v^{\circ\prime}_s\{1-\kappa_1 e^{x\overline{\tau-\tau'}} \cos(y\overline{\tau-\tau'}+\varepsilon_1)\} \quad . \quad . \quad . \quad . \quad (29)$$

For $\tau>\tau'$, when there is a new yawing moment applied at τ', increasing linearly from zero at time τ' to C'_{n1} in time τ_1, the secondary (additional) motion is given by an equation of the form of (27), with appropriate substitutions, that is, for example

$$v^\circ=\frac{v^\circ_{s1}{}'}{\tau_1}\{\kappa_2 e^{x\overline{\tau-\tau'}} \cos(y\tau-\tau+\varepsilon_2)-(\overline{\tau-\tau'}+k_2 \cos \varepsilon_2)\} \quad . \quad . \quad (30)$$

2.5. *Particular forms of applied yawing moment*

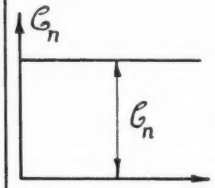
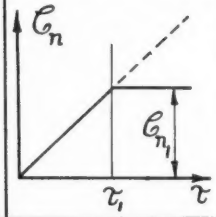
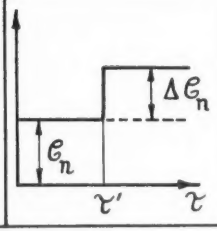
Three particular forms are considered, as follows :—

1. Instantaneous application of a constant value of C_n
2. Linear application of C_n, rising to an arbitrary maximum, and thereafter maintained constant.
3. Instantaneous application of a constant value of C_n followed, after a delay, by an instantaneous change in the constant value.

The solutions for these particular cases can be derived quite simply from the equations above, and are tabulated for convenience in Table 1.

TABLE I

SOLUTIONS

FORM	$\mathcal{C}_n$ VARIATION	PRIMARY MOTION $\hat{V}$	SECONDARY MOTION $\hat{V}'$	SOLUTION
1		$\hat{V}_S\left\{1 - k_1 e^{x\tau}\cos(y\tau+\epsilon_1)\right\}$	NONE	$\hat{V}$
2		$\frac{\hat{V}_{S1}}{\tau_1}\left\{\begin{array}{l}(\tau + k_2\cos\epsilon_2) \\ -k_2 e^{x\tau}\cos(y\tau+\epsilon_2)\end{array}\right\}$	$-\frac{\hat{V}_{S1}}{\tau_1}\left\{\begin{array}{l}(\overline{\tau-\tau_1} + k_2\cos\epsilon_2) \\ -k_2 e^{x.\overline{\tau-\tau_1}}\cos(y\,\overline{\tau-\tau_1}+\epsilon_2)\end{array}\right\}$	$\tau < \tau_1 :\sim$ $\hat{V}$ $\tau > \tau_1 :\sim$ $\hat{V} + \hat{V}'$
3		$\hat{V}_S\left\{1 - k_1 e^{x\tau}\cos(y\tau+\epsilon_1)\right\}$	$\Delta\hat{V}_S\left\{1 - k_1 e^{x.\overline{\tau-\tau}'}\cos(y\,\overline{\tau-\tau}'+\epsilon_1)\right\}$	$\tau < \tau' :\sim$ $\hat{V}$ $\tau > \tau' :\sim$ $\hat{V} + \hat{V}'$

NOTE: SIMILAR SOLUTIONS FOR $\hat{r}$ CAN BE DERIVED IF DESIRED FROM EQNS (12) & (28)

In the paper the symbols v°, r° and t° are used instead.

2.6. *Maximum sideslip*

When C_n is independent of τ we have shown that maximum sideslip occurs when $\tau = n\pi/y$. In a damped oscillation the first swing gives the greatest maximum. Taking $n=1$ and substituting for τ in (11) we have

$$v^\circ_m = v^\circ_s \{ 1 - \kappa_1 e^{x\pi/y} \cos(\pi + \varepsilon_1) \} \quad . \quad . \quad . \quad . \quad . \quad (31)$$

Thus

$$\frac{v^\circ_m - v^\circ_s}{v^{\circ s}} = \kappa_1 e^{x\pi/y} \cos \varepsilon_1$$

$$= e^{x\pi/y} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

Thus we can take x/y as a measure of the maximum value of "overswing," defined as

$$(v^\circ_m - v^\circ_s)/v^\circ_s$$

We have

$$x/y = -(n_2 + \bar{y}_v)/2\sqrt{\{ (n_2\bar{y}_v + N) - (n_2 + \bar{y}_v)^2 \}}$$

$$= 1 \Big/ \left\{ 2\sqrt{\frac{n_2\bar{y}_v + N}{(n_2 + \bar{y}_v)^2} - 1} \right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (33)$$

We can thus plot overswing against the quantity

$$F = (n_2 + \bar{y}_v)^2/(n_2\bar{y}_v + N)$$

which, translating into the usual notation becomes

$$F = (n_r + i'_c y_v)^2/i'_c(\mu_2 n_v + n_c y_v) \quad . \quad . \quad . \quad . \quad . \quad (34)$$

A curve of percentage overswing plotted against F is given in Figure 1.

2.7. *Curves of maxima and minima*

A curve passing through all the maximum or minimum points of the oscillation is of use in drawing a curve of v° against time.

For constant C_n, this curve is given by

$$v^\circ = v^\circ_s(1 \pm e^{x\tau}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

3.0. APPLICATION IN PRACTICE

The routine use of the method presented in this paper would be as follows :—

(a) Estimate for a series of fin and rudder sizes the values of the derivatives n_{v_F}, n_v, y_v, n_r, a rough approximation to i'_c being made at the same time.

(b) For each fin size work out the value of the factor F and read off the corresponding value of overswing percentage from Figure 1.

(c) Estimate the yawing moment expected from the cutting of the most adverse engine under appropriate conditions of speed and power, and hence the steady sideslip v°_s.

(d) The maximum sideslip reached is then immediately obtainable from v°_s and the percentage overswing.

(e) A curve of maximum sideslip against fin size (in terms of n_{v_F}), can then be plotted.

At this stage it is necessary to point out that linear characteristics have been assumed throughout. Some empirical allowance must be made in practice for the non-linearity which is to be expected.

A recommended fin size can then be chosen, by taking that value of n_{v_F} which leads to a maximum sideslip not greater than 75 per cent. to 80 per cent. of the anticipated fin stalling angle.

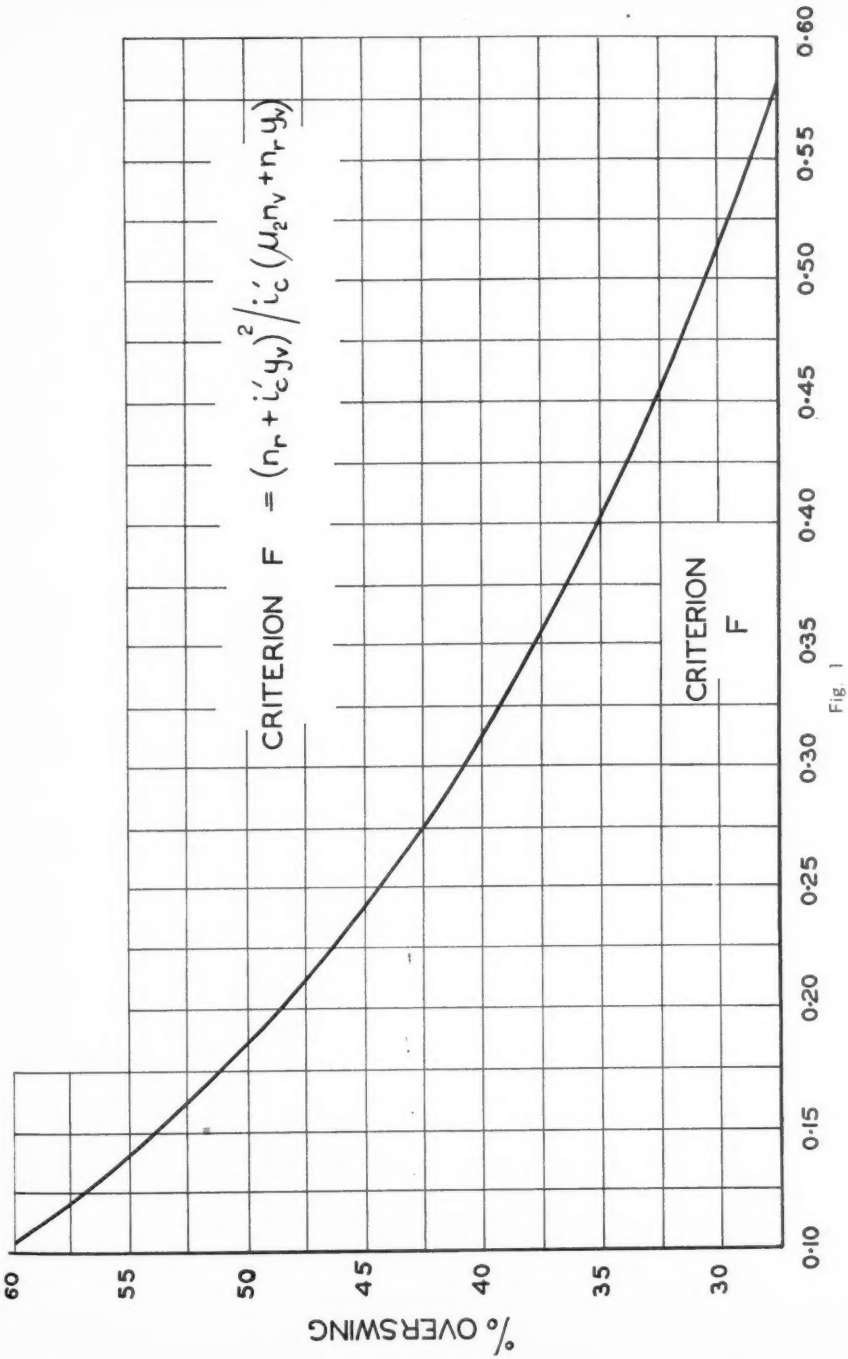

% OVERSWING
60
55
50
45
40
35
30
0·10
0·15
0·20
0·25
0·30
0·35
0·40
0·45
0·50
0·55
0·60
CRITERION F
CRITERION F = $(n_r + i'_c y_v)^2 / i'_c (\mu_2 n_v + n_r y_v)$

Fig. 1

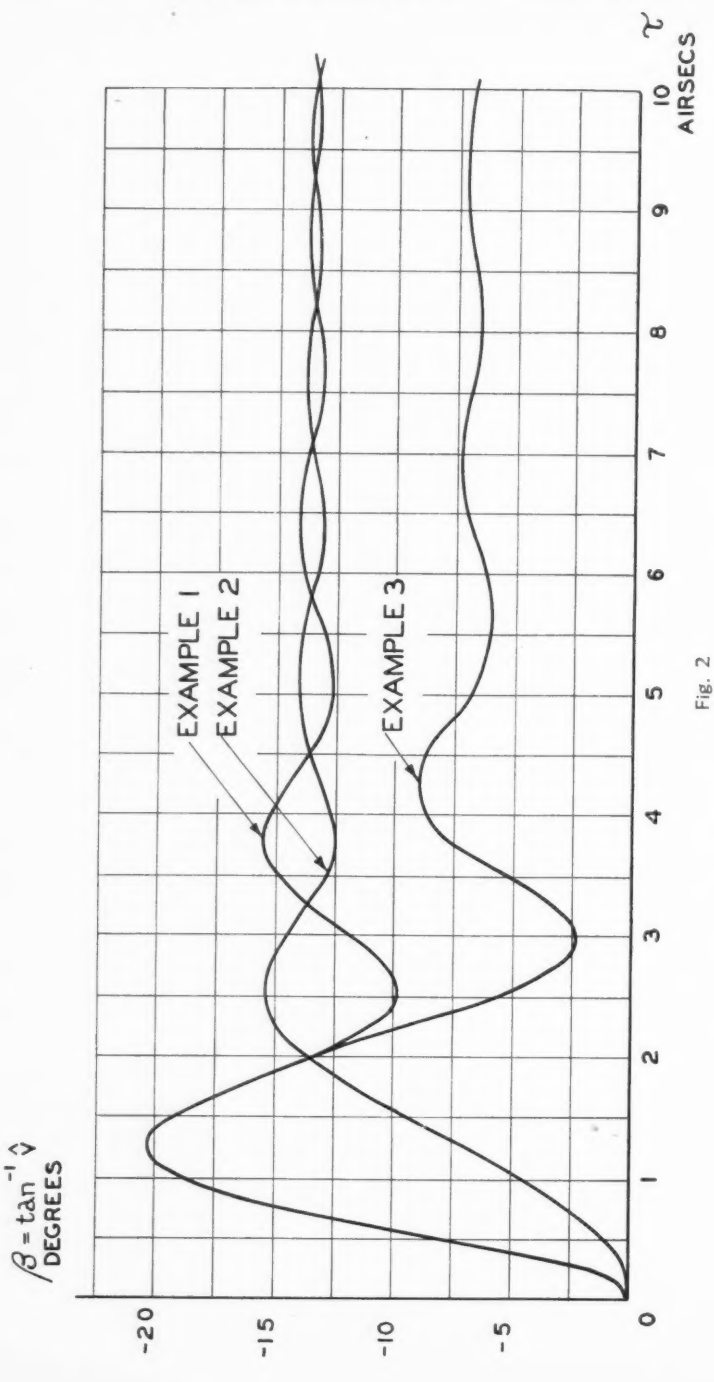

$\beta = \tan^{-1} \hat{v}$
DEGREES
-20
-15
-10
-5
0
1
2
3
4
5
6
7
8
9
10
AIRSECS
τ
EXAMPLE 1
EXAMPLE 2
EXAMPLE 3

Fig. 2

4.0. TYPICAL EXAMPLES

Six examples have been calculated, all the data used being given in Appendix 2. The examples can be summarised as follows :—

Example 1. This example demonstrates the constant yawing moment form.

2. This example demonstrates the time linear form, reaching a maximum and thereafter constant.

3. This example demonstrates the response to a constant yawing moment with a sudden change after a delay.

The motions for these three examples are plotted in Table 2. It will be seen that the gradual application of yawing moment reduces and delays the maximum sideslip reached, while the particular delay chosen for Example 3 does not appreciably alter the maximum sideslip.

Examples 4. and 5. These examples demonstrate, when compared with Example 1, the effects of a change in fin size and a constant applied yawing moment.

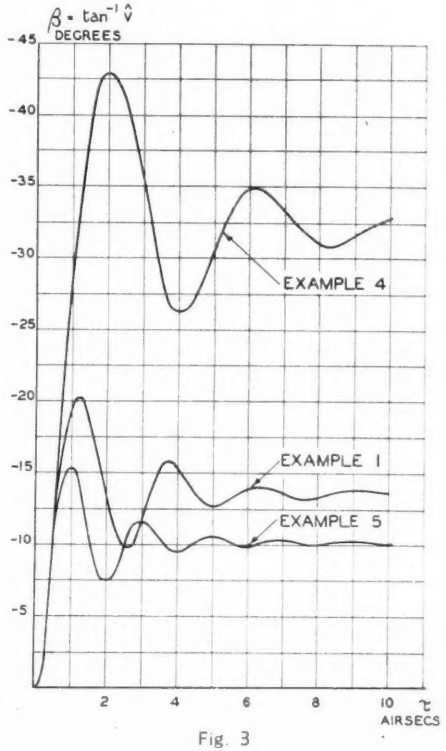


Fig. 3

The motions for these two examples are plotted, together with that for Example 1 in Figure 3. The effect of an increase in fin size, affecting both maximum and steady sideslip, as well as the degree of damping, is clearly shown.

Example 6. This example is similar to Example 1 but is at twice the flying speed.

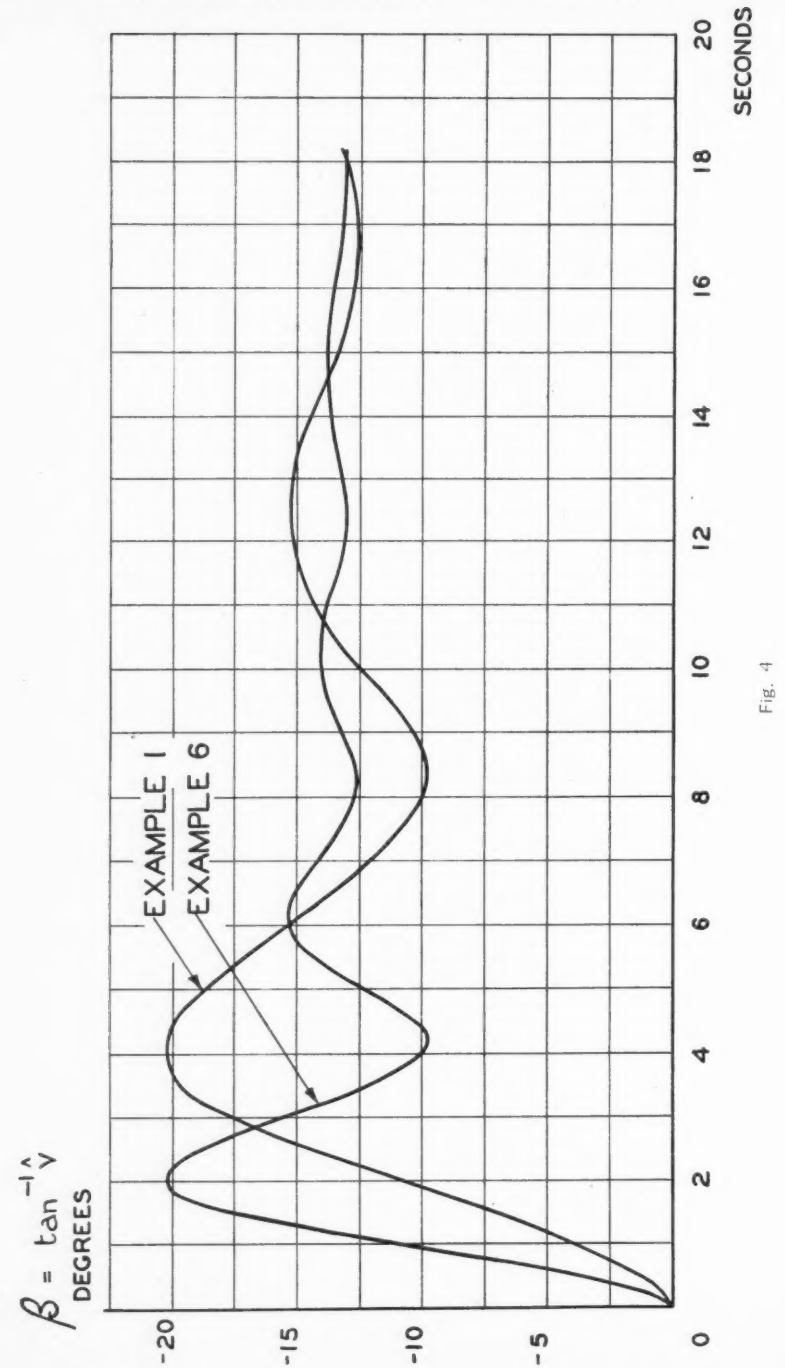

β = tan⁻¹ v̂
DEGREES
-20
-15
-10
-5
0
2
4
6
8
10
12
14
16
18
20
SECONDS
EXAMPLE 1
EXAMPLE 6

Fig. 4

Motions for Examples 1 and 6 are plotted together on a common basis of *true* time in Figure 4, showing that the only difference between the two motions lies in the value of the airsec as affected by speed.

5.0. CONCLUSIONS

Solutions, in a comparatively simple form, have been obtained for the restricted equations of motion appropriate to zero bank. A quick and convenient method of estimating the maximum sideslip in a given case has been demonstrated, leading to a method of fixing fin size in the initial design stage according to engine cutting requirements.

REFERENCE

(1) R. & M. 1801 .... Nomenclature for stability coefficients. L. W. Bryant, B.Sc., and S. B. Gates, M.A., October, 1937.

APPENDIX I.

TABLE OF NOTATION.

b	=	span of aircraft, ft.	β	=	angle of sideslip $tan^{-1}v^\circ$	
D	=	$d/d\tau$	ε_1	=	constant of integration	
E	=	constant of integration				see equation (9)
F	=	see equation (34)	ε_2	=	,, ,, ,,	(25)
K	=	constant of integration	κ_1	=	,, ,, ,,	(10)
l	=	fin moment arm in terms of $b/2$	κ_2	=	,, ,, ,,	(26)
m	=	see equation (4)	τ	=	time in airsecs.	

The notation used in equations (1), modified here for typographical reasons, was put forward by Mitchell in May, 1943, as an attempt to simplify manipulations of the full equation of motion. No great advantage derives from its use here but it is thought advisable to be consistent with current papers on similar subjects. The meanings of the symbols used in equations (1) are given blow :—

$$\bar{y}_v = -y_v \qquad n_2 = -n_r/i'_c$$
$$N = \mu_2 n_v/i'_c \qquad C_n = \mu_2 C_n/i'_c$$
$$v^\circ = v/U_c \qquad r^\circ = rt^\circ$$

Here, y_v, n_v, n_r, i'_c, μ_2, v, r and C_n have the usual meanings given by Bryant and Gates (Ref. 1), U_e, however, replacing V for the undisturbed velocity.

The symbol t° represents the value of the aerodynamic unit of time, the airsec, in seconds.

Thus $t^\circ = W/g\rho SU_e$ seconds.

The meanings of the remaining symbols are given in the above table of notation.

APPENDIX 2.

Data for Typical Examples.

Example		1	2	3	4	5	6
C_n variation		1	2	3	1	1	1
U_e	ft./sec.	200	200	200	200	200	400
n_v		0·08	0·08	0·08	0·03	0·13	0·08
n_r		−0·10	−0·10	−0·10	−0·06	−0·14	−0·10
y_v		−0·30	−0·30	−0·30	−0·20	−0·40	−0·30
C_n		0·02	—	—	0·02	0·02	0·02
C_{n1}		—	0·02	—	—	—	—
ΔC_n		—	—	−0·01	—	—	—
τ_1		—	2·00	—	—	—	—
τ'		—	—	2·00	—	—	—
κ_1		1·0207	—	1·0207	1·0281	1·0209	1·0207
κ_2		—	0·4026	—	—	—	—
ε_1	degrees	−11·55	—	−11·55	−13·44	−11·62	−11·55
ε_2	,,	—	246·92	—	—	—	—
x		−0·5072	−0·5072	−0·5072	−0·3643	−0·6500	−0·5072
y		2·4841	2·4841	2·4841	1·5251	3·1583	2·4841

Data Common to All Examples.

b = 120 ft.
w = 75,000 lb. wt.
S = 1,500 sq. ft.
Altitude = Sea level
i'_c = 0·14
μ_2 = 10·874
$t°$ (cases 1, 2, 3, 4, 5) = 3·262 secs.
$t°$ (case 6) = 1·631 secs.

THE ROYAL AERONAUTICAL SOCIETY

Paper received January, 1946

THE de HAVILLAND WING TEST RIG

by

W. HAMPTON, Graduate

Mr. Hampton joined the de Havilland Aircraft Co., Ltd., at Hatfield as a Trade Apprentice in 1938 *and the following year entered the D.H. Technical School as a student. After completing his course in the workshops and Drawing Offices at de Havilland's he joined the Stress Office Staff in* 1943. *Since then he has spent some time in the Test Laboratory and has gained considerable experience in the testing of major aircraft components.*

A DESCRIPTION of a test made recently in this test rig should prove of interest to those engaged in the design, stressing and structural testing of large aircraft structures, particularly wings, in that it would appear to represent a considerable advance over any previous test of this nature made in this country, and opens up new fields in simplicity and speed of application of the loads. The full load was applied to the wing in this test by one operator in approximately 50 seconds, thus approaching much more nearly than on any previous test made here the conditions which occur in flight.

The wing was tested in a structural steel test frame similar in construction, though much smaller in scale, to the well-known "Cathedral" Rig of the R.A.E. at Farnborough. All the loads were applied hydraulically and were controlled by one operator through a single valve. The loads were measured on the hydraulic system pressure gauge. In Fig. 1 the wing is shown rigged for test in the test frame—the wing is actually carrying a load equivalent to 3.g, in this photograph.

The lift loads outboard of the engine were applied at either two or three points across the chord at each rib position, the brackets for the loading points having been built into the wing during manufacture. These loading points were connected together by means of a suitable system of levers and linkages so that all the lift loads on the wing outboard of the engine could be applied by means of a single hydraulic jack.

Inboard of the engine, *i.e.*, between the engine and the fuselage side, the lift loads on the main ribs and on the radiator support ribs were linked together by means of a smaller system of levers and were applied by a second smaller hydraulic jack. The anti-lift loads (*i.e.*, fuel weight and engine, undercarriage, oil weights, etc.) were all applied through a further linkage system beneath the wing by means of a third hydraulic jack.

The test was made on a full-span wing and three more jacks were arranged in a similar manner on the opposite side of the wing, symmetrically disposed about the centre line of the aircraft, thus using six hydraulic jacks in all.

The wing was held down on the centre line of the aircraft by means of a dummy front and rear fuselage constructed of structural steel and attached to the wing at the wing-to-fuselage main joints. Anti-lift loads due to fuel and other equipment in the wing centre section were applied automatically by linking these in with the front fuselage reaction by means of a suitable lever system, as shown in Fig. 2.

As this was to be a test of the wing main structure, the aircraft engine mountings were replaced by dummy mountings of

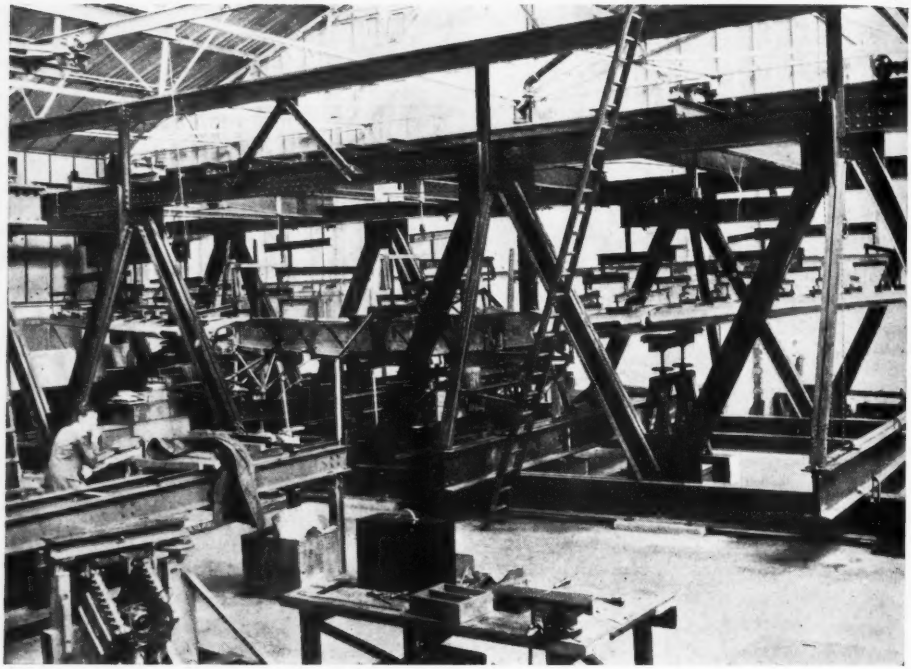


Fig. 1
Wing in Test Rig.

structural steel in order to ensure that these items should conform to the general safety factor of the test rig; the radiator support ribs were similarly replaced.

Now the essential feature of the simplicity of the test method lies in the fact that the lever systems were so arranged that the same oil pressure was required in all six hydraulic jacks to give the correct loads. In other words, all six jacks were connected to the same source of oil pressure and all the loads were applied at once by the opening of a single valve. In order to obviate the necessity of using three different sizes of jacks, with possibly peculiar piston diameters, a correcting lever was installed where necessary between the jack and its lever system as shown in Fig. 2, thus enabling two standard types of jack, one five inches diameter, 20 tons capacity, and one three inches diameter, 7 ton capacity, to be used throughout the test.

The pumping unit used is shown in Fig. 3, and diagrammatically in Fig. 4. It consists basically of an electrically-driven pump, pumping oil from the supply tank into the hydraulic accumulator. At a predetermined oil pressure (2,500 lb./in.^{2} in this test) the cut-out valve opens and allows the oil to circulate freely back to the tank. When the "load on" needle valve is opened oil is fed from the accumulator into the pressure reservoir from which radiate the pipes leading to the six loading jacks. A pressure gauge is also connected to the pressure reservoir; for this test a gauge having a twelve inch diameter dial was used and was calibrated in lb./in.^{2} and also in percentages of the fully factored load. A further pipe from the pressure reservoir leads back

FIG. 2 DIAGRAM SHOWING METHOD OF LOADING WING.

through the "load off" valve to the supply tank.

A flow control valve was fitted to enable the supply of oil to be cut off from one or the other (but not both) of the port and starboard outboard lift jacks, in order to control any possible tendency of the wing to rock to one side for unforeseen reasons during the test. A study of Fig. 2 will show that it is permissible to cut off the supply

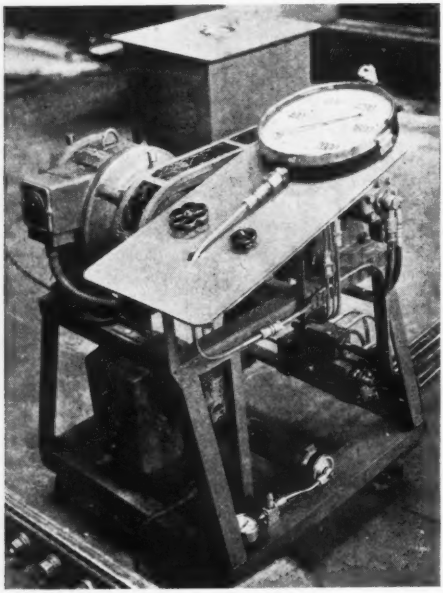


Fig. 3
Pumping Unit.

of oil to one of these jacks without altering the applied loads, since one of these jacks could actually be replaced by a link without affecting the reactions. In fact, during the test it was found that there was no tendency for the wing to tip and this control valve proved unnecessary, although this should not be taken as an indication that such would always be the case.

The hydraulic accumulator served a double purpose. First, its capacity was such that increments of load corresponding to 2.g could be applied by the accumulator alone in absolute silence, a valuable feature on tests of this nature where the slightest noise from the test specimen under load may give warning of impending collapse. Second, during the final test to destruction which was done rapidly with the motor pump running, the accumulator served to smooth out any small fluctuations in the oil pressure caused by the cutting-in and -out of the pump and to slight irregularities in the pump delivery.

The hydraulic jacks which were designed and manufactured specially for this test were of a straightforward construction and have proved entirely reliable. In spite of the relatively high oil pressure used (by ordinary engineering standards), no trouble was experienced with leakage throughout the series of tests. The pipe lines which were of $\frac{1}{2}$" o/d copper with standard A.G.S. joint fittings were sealed off and proof loaded to 2,500 lb./in.^{2} prior to the test and the jacks themselves were loaded to their full working loads during calibration.

Before the test each jack was separately calibrated in a testing machine, and charts were drawn showing the error throughout the range of loads. A mean error curve was drawn for all six jacks, and a correction was applied to the pressure gauge reading for each increment of load. The error of actual load against theoretical was found in every case to be very small, less than 1% at values above 50% of the working load.

Aircraft hydraulic fluid was used for the system, and was found to be entirely satisfactory. Small pressure gauges were inserted in the oil line at points farthest away from the loading unit in order to check that there was no delay or unevenness in the pressure distribution and this proved to be the case.

Numerous tests and demonstration loadings to 40% and 50% were made before the final series of tests, in which the wing was broken, and it was found that the wing could be loaded easily to 50% and the load released again in less than 30 seconds.

It will be seen that slight modifications to

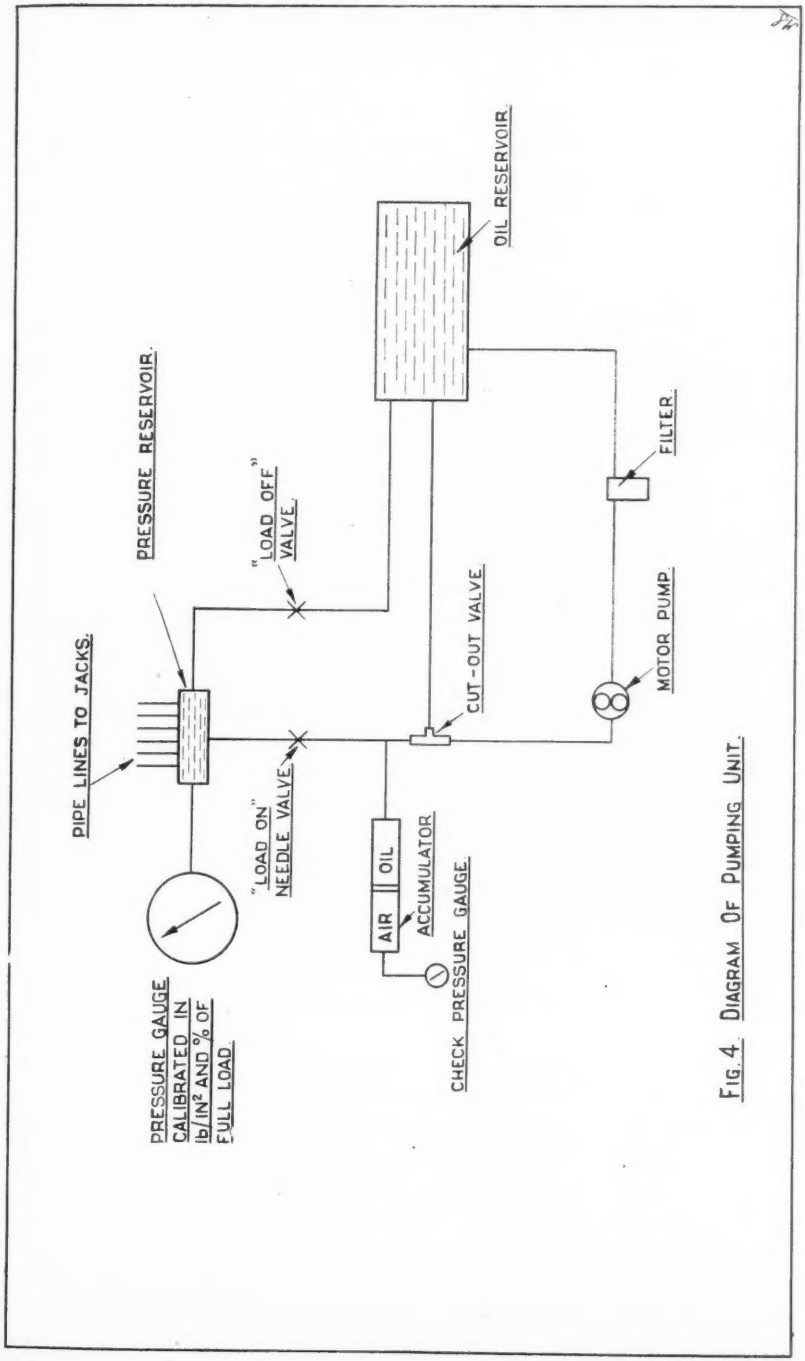


FIG. 4. DIAGRAM OF PUMPING UNIT.

the loading unit to incorporate automatic valves and a counting mechanism would enable repeated loading tests to be made. The author considers that between 750 and 1,000 loadings to proof load (75%) per day, or 10,000 cycles in 12 days, could readily be achieved using this equipment, at a cost very little in excess of a single test to destruction.

In view of the recent investigations of the R.A.E. and others attaching greatly increased importance to the strength of wings under repeated loads, it seems likely that in future, designers may wish to carry out tests of a more elaborate nature than in the past. Repeated loading tests may become equally, or even more, important than the simple tests to destruction which are common at the present time. The author has attempted to outline here a relatively simple method of achieving this aim by describing a system which is known to function in a very satisfactory manner.

The author is indebted to Mr. C. C. Walker and Mr. R. E. Bishop of the de Havilland Aircraft Co., Ltd., for their permission to publish this paper, and to Mr. R. H. T. Harper and Mr. W. J. Winkworth for their encouragement and helpful criticism.

REVIEWS

Jane's All the World's Aircraft 1945-46.

Edited by Leonard Bridgman. Sampson Low, Marston & Co., Ltd., London, 1946. £3 3s. 0d. net.

Aviation without Jane's is like a dinner without H.P. sauce. The first post-war edition is one of revelation, as the 1919 edition was, of much which had been kept secret for so many years. The editor and publishers very wisely decided to delay publication a few months so that all available information up to the beginning of 1946 could be incorporated.

This is, indeed, all the World's aircraft, and for the first time since the surrender of the Axis powers a complete survey can be made of the military aircraft which swept the troubled skies for nearly six years.

Jane's is far too well-known as an established authority to give a detailed review, and only a few of the high lights can be mentioned. As the Law Reports are necessary to a barrister, so is Jane's to the aircraft and aero-engine designer and the historian. In the Royal Air Force a new series of posters is now being put up in all R.A.F. messes, "Fly with Prudence." A new series might equally well be put up in aircraft offices, "Fly to Jane—she knows the answers."

J. M. Spaight has written an excellent summary of what the war in the air has meant, "the triumph of air power was glittering and unmistakable."

It is followed by the two sections of Historical Survey of Service Aviation and Civil Aviation.

The section on all the World's aeroplanes has a special 24-page addenda to bring it up to date. Here descriptions are found of the latest machines from the D.H. Dove and Vampire to the Gloster Meteor and Handley Page Manx Experimental tailless monoplane.

Jane's reveals the bitter story of the heavy losses of the French Aircraft Industry under German occupation and Allied bombing. There are no illustrations of French aircraft in these pages, in itself a significant comment of the state of the Industry.

The description of German aircraft is excellent, ending with details of the V1 and V2 weapons. One is not surprised to find how pooly Italy comes out, how utterly its engineers and designers failed under the stresses of war and Mussolini.

As with the pages devoted to German aircraft, so with those given to Japanese. They are full and informative, and end with brief interesting notes on suicide aircraft and the Baka flying bomb.

Details of the distribution of the Russian Aircraft Industry were not available and the descriptions given are of some of the more recent types of aircraft produced in the State Factories.

It is interesting to find in the American section, apart from the descriptions of the military effort, details of transport aircraft and helicopters.

For the first time there is a section devoted to the gas turbine, a section which, if its enthusiasts are to be believed, will be the only section in a few years devoted to aircraft engines. One is inclined to suspect, however, that there is a little too much hot air going through the turbine at the moment, and the teething troubles of practical experience will have a considerable cooling effect. But the section is significant of coming events, and is a timely record of the magnificent efforts of British designers in this field.

One would like to give full marks to the editor and printer for the outstanding efforts they have made to produce Jane's once more in its pre-war dress. In the safe hands of Leonard Bridgman it will be leading aeronautical fashions again, as it has done for so many years.

The Gyroscope and its Applications.

Edited by M. Davidson, D.Sc., F.R.A.S. Hutchinson's Scientific and Technical Publications, London, 1946. 21/- net.

This book, under the able editorship of Dr. Davidson, is divided into three sections. The first deals with the general theory of the gyroscope, the second with its marine applications and the third with its aeronautical applications.

Section I is written by Dr. Davidson himself and he is to be congratulated on the simplicity and clearness of his exposition. He leads the reader so steadily up the gyroscopic path from the toy gyroscope of his boyhood days to the differential equations involved in calculating the damping of the oscillations of the gyro-compass that one feels no one with a reasonable grounding in mathematics or engineering should be unable to do all the necessary calculations for himself.

Section II is by G. C. Saul and is descriptive of the gyro-compasses as used in ships; the gyroscopic stabilisation of ships, and the gyroscope in the torpedo. The chapters in this section deal entirely and fully with these main uses of the gyroscope. There is much technical data still to be published of the interesting applications of the gyroscope for naval purposes.

Section III, by J. A. Wells, an Associate Fellow of the Society, and A. P. Glenny, on aeronautical applications is, undoubtedly, of most interest to readers of the Journal. Both are authorities on their subject.

The use of the gyroscope has gone far to make flying possible and safe in cloud and fog conditions and the development of the automatic pilot, to relieve pilots of the fatigue on

long flights, has been a very necessary requirement. As in Section II excellent descriptions are given of the development of modern gyroscopic instruments, such as the gyro-compass, rate of turn indicators and gyro verticals.

One chapter is devoted specially to the automatic pilot. The authors draw attention to the fact that the first automatic pilot was installed in an aeroplane as long ago as 1909 and a Curtiss flying-boat, fitted with a Sperry all-electric gyro stabiliser, won the Grand Prix for safety in 1914. In this country Cooke, Meredith and Kerr at the R.A.F. did sterling work to develop the R.A.E. automatic pilot.

There are many applications of the gyroscope which, under war-time secrecy, have not yet been released, and it is hoped that the authors will be able to include these in a future edition. Nevertheless this is an excellent book for the aircraft designer to have on his shelves, for it enables him to understand the full value of the use of the gyroscope to obtain automatic control.

The book is beautifully produced, and the publishers are to be congratulated on the quality of the setting, illustrations and paper.

Modern Petrol Engines.

A. W. Judge. Chapman & Hall, Ltd., London, 1946. £1 16s. 0d. net.

A. W. Judge has specialised for many years in the literature of engines. His two volumes on Aircraft Engines, and those on High Speed Diesel engines are well-known.

This new volume is intended to be for the use of the designer, engineer, draughtsman and student who are mainly concerned with petrol engines.

The author's new book is a very thorough study of the whole petrol engine field and one which should prove of great value to students and all those engaged in engine development.

Chapter I deals briefly with the History and Development; Chapter II the Combustion Process and Fuels; Chapter III Thermodynamics of the Petrol Engine; Chapter IV Petrol Engine Performance; Chapter V Supercharging; Chapters VI and VII Cooling; Chapter VIII Carburation and Fuel Inspection; Chapter IX The Two-cycle Engine; Chapter X Petrol Engine Types and Applications; Chapter XI The Single-sleeve Valve Engine; Chapter XII The Internal Combustion Turbine; Chapter XIII Some Ignition Considerations and the last Chapter, Lubrication.

There is an excellent series of over a hundred and fifty references at the end of the book which should prove invaluable to those who wish to inquire still further.

The book has been excellently produced under the present difficulties of printing and will be a valuable addition to any library on engines.

Scientific Instruments.

Edited by H. J. Cooper. Hutchinsons' Scientific and Technical Publications, 1946. 25/-.

This survey of the instruments at present used by the many sides of science has been compiled by a large number of authors, each an expert on a particular group of instruments. As a result each of the various sections is equally informative, an ideal which could not have been attained if one author had produced the whole book.

The method adopted by each author is to give a description of each instrument and the scientific basis of its working, together with brief notes on its use. Illustrations are used to good effect and whenever necessary a short history of the type of instrument is given to assist the reader in the understanding of the theory. One point which will be greeted with great joy by many is that the authors have only used the minimum amount of mathematics, and that which is used is of an extremely elementary nature.

No attempt has been made to give complete and detailed information required for the use of each instrument, as this is a matter for a more specialised and less general book, but a reader who absorbs all the information will feel completely " in the picture " when he sees instruments which he has never met in practice.

The book is divided into five main sections: Optical, Measuring, Navigational and Surveying, Liquid Testing, and a miscellaneous group covering Acoustics, Calculating Machines, Hardness Indicators and Thermionic Valves. From this it should not be assumed that electrical methods are omitted, as these appear throughout and cover a multitude of instruments.

Even Aston's Mass Spectrograph and its descendants have left the quiet seclusion of the physical laboratories to take a more active part in the world of clocks, ammeters and thermometers.

Das Feld Einer Raschbewegten Schallquelle.

Nikolaus Rott. No. 9 Mitteilungen aus dem Institut für Aerodynamik, Eidg. Techn. Hochschule, Zurich, Herausgegeben von Prof. Dr. J. Ackeret. Zurich, 1945.

This paper, which has been prepared in collaboration with Professor Ackeret, Zurich, is a theoretical approach to analyse the characteristics of a field of sound as produced by a source at high velocities.

The theory by Doppler and Mach of wave motions as produced by a source in motion has hitherto been mainly applied to optical problems and the development in technical science has brought out problems of waves of sound produced by a source in motion.

Among the variety of problems connected with the source of sound in motion the author deals with the study of the characteristics of a steady linear motion.

The principle of Doppler is discussed and a clear development of the basic acoustic equations and the method for solution is given, introducing the Voigt method of substitution, to be applied to the differential equations for the sound potential in parallel flow of constant velocity.

Further, the case is discussed of small stationary disturbances, such as a source or sink, in a parallel flow of a comprehensible fluid, the kinematic of the Doppler-Mach-spheres in the parallel flow, the various geometric relations in the field of sound, pressure exerted by the sound wave at various Mach numbers, and the mass flow per unit area and unit time, produced by the acoustic disturbance are discussed in detail.

In the final chapters the book deals with the application of the theory to the problems of aeroplanes at various Mach and acoustic ground interference.

A reliable contribution to existing theory of fluid mechanics that should be made available to all those who are interested in the subject.

Dictionary of Aeronautical Terms.

Group Captain H. Nelson, C.B.E., R.A.F. Sir Isaac Pitman & Sons, Ltd., 1946. 10/6 net.

From time to time there have been published Glossaries or Dictionaries of Aeronautical Terms. Nothing, however, is more difficult than that of defining in clear, unequivocal language, the words one uses. Dr. Joad has obtained a reputation by his phrase on the Brains Trust, " It all depends upon what you mean."

Group Captain Nelson has turned a blind eye to water-tight definitions, and gives a general explanation of aeronautical terms in use. In that particular way the book is a useful one. But it is packed with terms which are not purely aeronautical, and descriptions which are not those within the compass of the dictionary, useful though they may be from the point of view of mere knowledge.

For example, he defines Abrasives as materials used for grinding, scouring and polishing. Then follow some twenty lines of description of various kinds of abrasives and their use. The twenty lines strike one as being so much padding. The first two lines are sufficient and the rest could easily be deleted by suitable editorial abrasion.

The definitions of many terms are far too loose to be of any real value. For example, Buoyancy is described as " the conditions of floating," and adds " the vertical up-thrust on an aeroplane, resulting in an aerodynamic reaction of the relative wind across its various lifting surfaces, when numerically equal to the weight of the machine, produces a condition of buoyancy."

Tables for Measurement of Oil.

Institute of Petroleum, London, 1945. 25/- net.

There has been a need for many years for authoritative figures for the fundamental units of measurement used in the petroleum industry, and for the necessary tables.

These tables have now been prepared in Imperial Units, to meet the special needs of industry in British territories by the Measurement and Sampling Sub-Committee of the Institute of Petroleum.

The tables in this book fall into two main groups, those giving specific gravities against the weights of oil per unit volume or conversely, and those which show the effect of temperature in oil volumes and specific gravities. The former group are new and the latter based on Circular C410 of the U.S. Bureau of Standards.

This is a timely publication which will be invaluable to the industry, particularly throughout the British Commonwealth and Empire.

THE SOCIETY'S AWARDS

The Society offers a number of valuable awards, most of them annually. Full particulars of the conditions attaching to these awards may be obtained on application to the Secretary.

Society's Gold Medal

This is the highest honour which the Society can confer for work of an outstanding or fundamental nature in aeronautics.

British Gold Medal for Aeronautics

The British Gold Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

The Simms Gold Medal is awarded annually for the best paper read in any year before the Society on any science allied to aeronautics, e.g., meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

The Taylor Gold Medal is awarded annually, at the discretion of the Council, for the most valuable paper submitted or read during the previous session.

Wakefield Gold Medal

The Wakefield Gold Medal is awarded annually to the designer of any invention or apparatus tending towards safety in flying, and is open to members or non-members.

Society's Silver Medal

The Society's Silver Medal is awarded, at the discretion of the Council, for some advance in aeronautical design.

British Silver Medal for Aeronautics

The British Silver Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Society's Bronze Medal

The Society's Bronze Medal is awarded, at the discretion of the Council, under the same conditions as those for the Silver Medal, but for some less important advance in aeronautical design.

Wilbur Wright Memorial Premium

The Wilbur Wright Memorial Lecture is held annually, a premium of seventy-five pounds being awarded to the lecturer invited by the Council to deliver the lecture. The lecture is usually given alternately by an American and an Englishman, and is the most important aeronautical lecture of the year. It is delivered whenever possible, on the last Thursday in May of each year.

British Empire and Commonwealth Lecture

The Council of the Royal Aeronautical Society have completed the arrangements for the founding of a British Empire and Commonwealth Lecture.

The lecture, on any aeronautical subject approved by the Council, will be delivered annually in September in London, by a lecturer, chosen in alternate years from the British Dominions and Colonies and Great Britain.

The Council, by founding this British Empire and Commonwealth Lecture, are anxious to encourage new ideas and new points of view from all parts of the British Empire and Commonwealth, and to make the Lecture second only in importance to the Wilbur Wright Memorial Lecture.

The British Empire and Commonwealth Lecture will have a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance will be paid towards the Lecturer's expenses.

R.38 Memorial Prize

The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

The Herbert Akroyd Stuart Lectures

Under the will of the late Mr. Herbert Akroyd Stuart a sum of £700 is held in trust by the Society for the offer of a prize every two years, for the best paper or lecture read or given before the Society dealing with the Origin and Development of Heavy-oil Aero Engines. The prize is open to members and non-members.

Edward Busk Memorial Prize

The Edward Busk Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes). Its value is twenty guineas.

Pilcher Memorial Prize

The Pilcher Memorial Prize is offered annually, at the discretion of the Council, for the best paper by a Student on heavier-than-air craft or any analogous subject. Its value is five guineas.

Usborne Prize

The Usborne Prize is offered annually, at the discretion of the Council, for the best paper by a Student on some subject in connection with Aero Engines. Its value is five guineas.

Major Baden-Powell Memorial Prize

The Major Baden-Powell Memorial Prize is awarded in May and December of each year to the student who is considered the best student by the examiners in the Society's Association Fellowship examinations. Its value is three guineas.

Elliott Memorial Prize

The Elliott Memorial Prize is awarded twice yearly to the apprentice at Halton who has the highest percentage of marks in the passing-out examination. Its value is 2½ guineas for each award.

R. P. Alston Memorial Prize

The R. P. Alston Memorial Prize is awarded to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control. Its value is approximately £5.

Branch Prize

The Council offer an annual prize of twenty guineas for the best paper read before the Branches during the previous lecture Session. The prize is open to any member of the Society or of any Branch.

Journal Premium Awards

The Council has set aside an annual sum of £250 to be given as premium awards to authors of papers published in the Journal.

AN APPRECIATION

The Council of the Royal Aeronautical Society wish to thank those Companies who, by their generous co-operation, have done so much to help in the production of the Journal in its new form.

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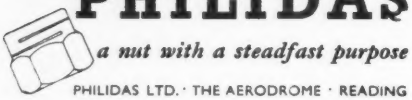

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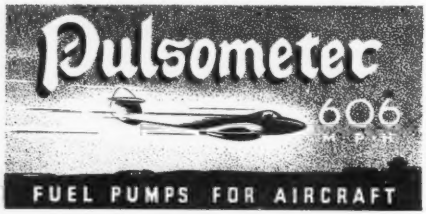

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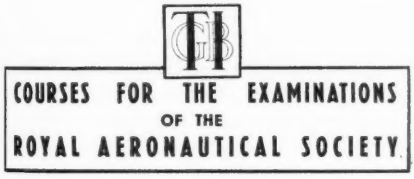

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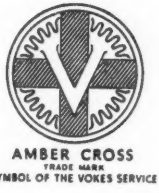

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